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ORIGINAL ARTICLES

STUDIES IN THE PERIODIC PARTIAL FAILURES OF THE PUNJAB-AMERICAN COTTONS IN THE PUNJAB

XII. FURTHER EXPERIMENTS ON THE AMELIORATION OF *TIRAK**

By R. H. Dastur,† Mukhtar Singh and Sucha Singh, Punjab Agricultural College, Lyallpur

(Received for publication on 29 June 1943)

The importance of June sowing as an ameliorative measure for *tirak*, occurring on the two soil types, viz. sandy loam with saline subsoil and light sandy soil deficient in nitrogen, has already been demonstrated by Dastur and Mukhtar Singh [1942; 1944]. It was also pointed out that the application of sulphate of ammonia on the former soil type was a total failure, whereas its use on the latter was highly effective. There are, however, lands where both the *tirak*-promoting soil-conditions co-exist. Light sandy soils deficient in nitrogen are also found to contain saline or alkaline subsoil A brief reference to *tirak* amelioration on such fields must be made, before further evidence on the success of the three ameliorative measures, namely, nitrogen, water and late sowing, under the different soil conditions, is presented and discussed.

Investigation

A. Amelioration of tirak

A field, where the worst form of *tirak* was observed in the cotton season of 1937 was selected at the Lyallpur Agricultural Farm for experimentation. The mechanical analysis of the soil showed that it generally contained about 76 per cent of sand in the upper 2 ft. At places, the sand was as high as 80 per cent on the surface and seedlings died soon after germination on such spots. The third and the fourth feet had comparatively lower percentage of sand. The sand fraction, however, increased again from the fifth foot, till it was practically all sand below.

The chemical analyses revealed the presence of varying amounts of sodium clay at different depths. Wherever sodium clay was present in the upper 2 ft., the growth of plants was stunted.

Over major portion of the field, plants made good growth up to August, when they began to show symptoms of nitrogen starvation, i.e. yellowing and reddening of leaves. The bearing was normal, but the individual bolls were so imperfect in development on account of the aggravating influence of adverse subsoil that nearly 1000 bolls were required to give 1 lb. of *kapas*.

At some places, the plants became stocky with short internodes. The leaves turned copper-coloured, curled upwards forming cups. On examination such leaves showed large quantities of starch in the mesophyll cells. The flowers appeared in clusters at the tips of the fruiting branches. The bolls formed were small containing highly immature seeds. Solitary flowers continued to be produced till late in the season, but they were usually shed. The examinaiion of the root system of such plants, on this field, showed vigorous main and secondary roots that were devoid of fine rootlets, the chief absorbing organs. The rootlets, however, were produced in large numbers, but they died soon after appearance leaving dark coloured scars at the points of emergence. It is highly probable that sodium clay with unfavourable *pH* in the subsoil was responsible for the above symptoms on these isolated patches.

A factorial experiment was laid out on this field in 1938 with the object of finding out the ameliorative effect, if any, of the three factors, namely, nitrogen, potash and the application of extra presowing irrigations. The last treatment was included to create subsoil reserve of water. The treatments comprised all combinations of:

Nitrogen	*Potash*	*Water*
o=No manure	*o*=No potash	*o*=No presowing waterings
g=Green manure berseem at 20 tons per acre	*k1*=120 lb. K_2O per acre	*w*=Two presowing waterings
m=Farmyard manure at 20 tons per acre	*k2*=240 lb. K_2O per acre	
n=Amm. sulphate at 90 lb. N per acre	*k3*=360 lb. K_2O per acre	

*This work was done in the Punjab Physiological (Cotton Failure) Scheme financed jointly by the Indian Central Cotton Committee and the Punjab Govt.

† Formerly Professor of Botany at the Royal Institute of Science, Bombay

A basal dressing of 80 lb. P_2O_5 per acre, in the form of superphosphate double, was given to all plots as a precautionary measure. As the soil was heterogeneous it was necessary to confound partially some of the high-order interactions. Block size was reduced to 8 plots instead of 32. Two complete replicates were provided.

Observations made during the season revealed similar behaviour of the plants, as already described for the previous cotton crop, with the difference that yellowing and reddening of leaves did not develop in the nitrogen-treated plots. Besides, the application of nitrogen encouraged vegetative growth, improved bearing and raised the yields but there was no amelioration of *tirak* (Table I). The increase in yield under nitrogen-application, therefore, resulted only from increased bearing. Neither potash nor presowing waterings were of much avail in the reproductive or the vegetative phase.

TABLE I

Treatment effects on the developmental characters and the yield—1938-39 experiment

(Light sandy soil with saline subsoil)

Treatment	Height per plant in cm.	Number of bolls per plant	Boll weight in gm.	Yield in lb. per 100 plants
No manure	96·4	26·2	1·219	5·41
F. Y. manure	116·3	32·9	1·332	8·40
Green manure	115·4	36·4	1·137	7·12
Ammonium sulphate	108·9	32·4	1·294	7·97
S. E.	*±3·93*	*±2·68*	*±0·089*	*±0·76*
No potash	106·9	32·3	1·199	6·36
Potash I	111·2	35·8	1·250	7·52
Potash II	108·0	28·8	1·226	7·11
Potash III	110·9	31·0	1·307	7·91
S. E.	*±3·93*	*±2·68*	*±0·089*	*±0·76*
Ordinary watering	109·9	31·0	1·197	6·76
Two extra presowing waterings	108·6	32·9	1·294	7·69
S. E.	*±2·78*	*±1·90*	*±0·063*	*±0·54*

1939-40

An experiment was conducted in the succeeding season in an adjoining piece of land under more or less similar conditions of the soil as described under the previous experiment. The aim was to confirm the previous findings and to explore the effects of the late sowing on *tirak* and the yield on the same theoretical grounds that governed its success on either of the two *tirak* soils. To obtain further evidence as to the dependence of late sowing on close spacing, the factor of spacing was also introduced. In addition to 4F, a *desi* short-stapled variety, known as Mol. 39, was included.

There were three replicates under the experiment. To the main plots were allocated 8 combinations of: two sowing dates ($d1$= 6-5-39, $d2$=10-6-39), two varieties (4F, Mol. 39) and two levels of inorganic fertilizer mixture [control vs. (50 lb. P_2O_5 + 50 lb. K_2O) per acre applied on 4 August]. The main plots were split for two levels of nitrogen (control 25 lb. N per acre applied on 4 August) and each plot thus formed accommodated two spacing types ($s2$=2 ft. × 3 ft., $s1$=2 ft. × 1½ ft.). Thus the layout was a split-plot design.

All the main effects and the significant interactions on the basis of the statistical analyses of the data collected from this experiment are given in Tables II to V, and are discussed below.

It is evident from Table II that there was a substantial increase in yield by the sowing, mainly through improvement in the opening of bolls and partly through increased bearing. Nitrogen did not ameliorate *tirak* but affected boll number favourably and thereby the yield. Significant effects of P+K and of spacing on boll number were not reflected in yield and should be reckoned to have arisen by chance. Mol. 39 outyielded significantly the 4F Punjab-American because greater number of bolls of the former matured normally. In the case of 4F, not only were the bolls fewer in number but they were also affected by *tirak*. It is to be noted that the normal boll size of *desi* cotton is about 1·5 gm. and of 4F nearly 2 gm.

TABLE II

Main effects—1939-40 experiment

(Light sandy soil with saline subsoil)

Treatments		Number of bolls per sq. yard			Boll weight in gm.			Yield of *kapas* in md. per acre		
		Mean	Diff.	±S. E.	Mean	Diff.	±S. E.	Mean	Diff.	±S. E.
Sowing date	*d1*	64·13	+8·09*	±3·121	1·178	+0·433**	±0·062	9·59	+4·02**	±0·535
	d2	72·22			1·611			13·61		
Varieties	*4F*	52·57	+31·22**	±3·121	1·323	+0·143*	±0·062	8·88	+5·44**	±0·535
	Mol. 39	83·79			1·466			14·32		
Phosphorus and potash	*o*	62·81	+10·75**	±3·121	1·380	+0·029	±0·062	11·18	+0·84	±0·535
	pk	73·56			1·409			12·02		
Nitrogen	*o*	61·01	+14·34**	±4·189	1·357	+0·076	±0·046	9·94	+3·32**	±0·319
	n	75·35			1·433			13·26		
Spacing	*s1*	73·25	−10·14**	±3·406	1·382	+0·025	±0·030	11·71	−0·22	±0·261
	s2	63·11			1·407			11·49		

The differential behaviour of sowing dates with nitrogen (or of nitrogen with dates), is shown in Table III. In the absence of nitrogen, the effect of late sowing on yield was specially high because boll size as well as boll number increased. In the presence of N, boll size improved by delayed sowing but there was no effect on boll number and, therefore, the effect in yield was of a lower order. The maximum yield was, however, recorded under *d2n*.

TABLE III

Interaction : Sowing date × nitrogen—1939-40 experiment

(Light sandy soil with saline subsoil)

Number of bolls per sq. yd.				Boll weight in gm.				Yield of *kapas* in md. per acre			
	d1	*d2*			*d1*	*d2*			*d1*	*d2*	
o	51·69	70·34		*o*	1·132	1·581		*o*	7·55	12·33	
n	*76·59*	*74·11*		*n*	*1·224*	*1·641*		*n*	*11·63*	*14·88*	
Diff : ±5·92	+24·90**	+3·77		Diff : ±0·066	+0·092	+0·060		Diff : ±0·45	+4·08**	+2·55**	
D. N. =	−10·56*	±4·189		D. N. =	−0·016	±0·046		D. N. =	−0·76*	±0·319	

The relation between sowing date and spacing is brought out in Table IV. Early-sown crop produced the same number of bolls at both the spacings provided, but a great increase in boll number occurred under late-sown crop spaced close. This effect appeared as a significant interaction on boll number and was simultaneously reflected in yield. Boll weight, however, improved by late sowing irrespective of the spacings.

N.B.—In all the tables of this paper,*=significant at 5 per cent level of significance and **=significant at 1 per cent level of significance

TABLE IV

Interaction : Sowing date × spacing—1939-40 experiment

(Light sandy soil with saline subsoil)

Number of bolls per sq. yd.			Boll weight in gm.			Yield of *kapas* in md. per acre		
	d1	*d2*		*d1*	*d2*		*d1*	*d2*
s1 (close)	64·27	82·22	*s1* .	1·169	1·595	*s1* .	9·14	14·28
s2 (wide)	*64·00*	*62·22*	*s2* .	*1·187*	*1·627*	*s2* .	*10·04*	*12·94*
Diff : ±4·817 .	—0·27	—20·00**	Diff : ±0·042	+0·018	+0·032	Diff : ±0·370	+0·90*	—1·34**
D. S. =	—9·86**	±3·406	D. S. =	+0·007	±0·030	D. S. =	—1·12**	±0·261

The two varieties did not respond equally to nitrogen (Table V). The response in the case of Mol. 39 was distinctly greater. It may again be noted that the source of increase in yield through N-applications was the boll number component alone and not the boll weight. Briefly stated, on light sandy soil with saline subsoil, the improvement in boll opening, through late sowing, was the same irrespective of the nitrogen level and the spacing adopted. But the yield response to delay in sowing varied in magnitude to the extent the boll number component was influenced, under the varying levels of the other factors. Nitrogen did not raise the boll weight, though some gain in yield resulted from increased bearing.

TABLE V

Interaction : Variety × nitrogen—1939-40 experiment

(Light sandy soil with saline subsoil)

Number of bolls per sq. yd.			Boll weight in gm.			Yield of *kapas* in md. per acre		
	4F	Mol. 39		4F	Mol. 39		4F	Mol. 39
o .	49·91	72·11	*o* .	1·289	1·424	*o* .	7·55	12·33
n .	*55·22*	*95·47*	*n* .	*1·358*	*1·508*	*n* .	*10·21*	*16·31*
Diff : ±5·92	+5·31	+23·36**	Diff : ±0·066	+0·069	+0·084	Diff : ±0·45	+2·66**	+3·98**
V. N. =	+9·02*	±4·189	V. N. =	+0·007	±0·046	V. N. =	+0·66	±0·319

B. Trials of the ameliorative measures

It could be inferred from the foregoing results and those aready published [Dastur and Mukhtar Singh, 1942; 1944] that late sowing as a measure for ameliorating *tirak* and maintaining or increasing yields was of general application while the response to N (or water) was primarly governed by soil conditions.

The evidence in support of the above findings was obtained from experiments conducted at Lyallpur with 4F Punjab-American cotton. Obviously, it was necessary to test them, on a wider basis, by laying out similar large-scale experiments in the different cotton-growing tracts in the Punjab, using the commonly-cultivated variety of American cotton of each tract. Apart from the trial of the three successful ameliorative measures alluded to, it was considered desirable to include, in such an experimental programme, one *desi* variety (Mol. 39) and more than one American strains. The extent to which the different varieties would respond to the ameliorative measures, particularly late sowing, could thus be explored.

It can scarcely be doubted that the ultimate test of the soundness or economics of a

measure is its trial under actual *zamindari* conditions. It is possible that the results obtained under standard agricultural practices may not hold good on cultivators' fields. Moreover, experiments on the *zamindars'* farms are of special value inasmuch as these farms serve as centres for disseminating information and form the nucleus of improvement. The experiments reported below were, therefore, mainly conducted on the farms of *zamindars* during the years 1940-1942.

1940-41

Description of experiments. The first series of confounded designs with subplot arrangement were laid out concurrently at Brucepur (Lyallpur), B.C.G.A. Farm, Khanewal (Multan), Convillepur (Montgomery), and the New Seed Farm, Sargodha. All combinations of four sowing dates, two watering types (normal and heavy) and two levels of nitrogen (o. 33 lb. N per acre) were tried in six blocks of eight plots each, confounding completely with block differences the second-order interaction D.W.N.

Levels:	(*c1* = Spare) (*c2* = Thorough)	×	(*4F*) (*Mol. 39*)	×
Factors;	Priliminary cultivation		Variety	

with six-fold replication. There were three restrictions on the randomized block arrangement, viz. (1) C.V.W. was completely confounded with block differences, (2) combinations of cultivation and variety lay in array strips, and (3) the array strips were split longitudinally into two substrips each, for the two sowing dates. The final size of the experimental subplot was 1/80 acre.

The other experiments at Lyallpur had four levels of nitrogen (o, 16 lb. N, 32 lb. N, 48 lb.N) as the main-plot treatments, in six blocks. By simultaneous double-splitting, the main plots were subdivided longitudinally into three strips, for three sowing dates (*d1* = 10-11 May, *d2* = 28-29 May, *d3* = 15-16 June) and transversely into four plots for four varieties (4F, LSS 289F/43, Mol. 39). The allocation of varieties to the transverse plots was random, with the restriction that sets of variety × nitrogen interactions were partially confounded with the transverse rows and balanced arrangement attained. At picking, the experimental subplot was 1/100 acre. The different types of soils were represented in these experiments. The nature of soil conditions under each experiment is stated along with the presentation of its results.

Treatment effects on the opening of bolls. Statistical analysis of the boll weights in the first series of experiments revealed that the linear response to dates was highly significant in case of all the three experiments, viz. Brucepur, Khanewal and Convillepur. The quadratic response appeared only at Convillepur. Sowing dates interacted with varieties whose mean boll sizes also varied widely. The main effect of nitrogen and its interaction with varieties came out significant only at Convillepur. The nature of effects for the individual experiments has been illustrated below by summary tables. Boll weights were not recorded at Sargodha.

Three or four varieties were accommodated in each main plot, as mentioned below:

Brucepur	Khanewal	Convillepur	Sargodha
289F/43	289F/43	289F/43	289F/43
LSS	K25	K25	LSS 4F
Mol. 39	Mol. 39	Mol. 39	Mol. 39

The size of the subplot after rejection of borders, was nearly 1/60 to 1/40 acre in the different experiments. Heavy watering was secured by rewatering the plots, to be so treated, 18-24 hours after the normal irrigation to all plots. Differentiation in irrigation started after manuring in August. Watering types had to be dropped at Convillepur (Montgomery) on account of good rains in August and September.

The respective sowing dates for the different experiments are given in parentheses in the tables of results.

The second set of experiments were conducted at the Lyallpur Agricultural Farm. One of the experiments studied all combinations of:

(*w1* = 3 week) (*w2* = Fortnight)	×	×	(*d1* = 18-20 May) (*d2* = 20 June)
Watering interval, during fruiting			Sowing date

It is evident from Table VI that at Brucepur better development of bolls was attained in the third and the fourth sowings. The increase was particularly marked in the Americans. The response to heavy watering was small and suggestive and to nitrogen insignificant.

The effectiveness of late sowing in mitigating *tirak* was still more pronounced at Khanewal (Table VII). There was a progressive increase in the weight of seed cotton per boll with every delay in sowing, in the case of the American strains. K25 was particularly benefited inasmuch as its boll size nearly doubled by 1½ months' delay in sowing. Mol. 39, on the other hand, maintained its boll size at the normal level in all the sowings. The higher mean boll size in *desi* as compared with the Americans, at Khanewal and Brucepur, was due to the fact

TABLE VI

Treatment effects on boll weight in gm. at Brucepur

(Sandy loam with saline subsoil)

	Dates / Varieties	*d1* (8/5)	*d2* (24/5)	*d3* (8/6)	*d4*(24/6)	*Mean*	
Dates (linear)=1·11**±0·32 . . .	289F/43	1·29	1·52	1·78	1·67	1·57	±0·029
Dates (quadratic) =—0·224±0·144. .	LSS.	1·42	1·58	1·90	1·68	1·65	
Watering=0·126±0·072 . . .	Mol. 39	1·58	1·64	1·72	1·82	1·69	
Nitrogen=0·015±0·072 . . .	Mean ±0·072	1·43	1·58	1·80	1·73	..	

that the former escaped *tirak* while the latter suffered greatly under early sowings.

At Khanewal also nitrogen applications were ineffective in raising the boll weight on account of salinity in the subsoil.

The effect of delayed sowings in increasing the size of the bolls was equally marked on light sandy non-saline soil of the Convillepur experiment (Table VIII) even though *tirak* was practically absent in the early sowing also. The boll size of 289F/43 improved considerably by late sowing while the response in case of Mol. 39, though progressive and proportionate, was smaller in magnitude. K25 behaved in a slightly different manner inasmuch as the highest boll weight was attained at the third sowing. Rains incidentally following irrigations during August and September induced jassid attack in K25. The damage was relatively greater in the later sowings and more so in the presence of nitrogen. It is remarkable that in spite of this disadvantage K25 produced the best boll under *d3*. The decline under *d4* influenced the mean boll weight of this variety and also accounted for the significance of the quadratic response to dates.

TABLE VII

Treatment effects on boll weight in gm. at Khanewal

(Light sandy soil with saline subsoil)

——	Dates / Varieties	*d1* (13/5)	*d2* (28/5)	*d3* (14/6)	*d4* (27/6)	Mean	
Dates (linear) =1·96**±0·36 . . .	289F/43	1·16	1·29	1·66	1·78	1·47	±0·05
Dates (quadratic)=—0·116±0·16 . .							
Watering =0·076±0·08 . . .	K25	1·09	1·45	2·00	2·12	1·66	
Nitrogen =—0·051±0·08 . . .	Mol. 39	1·74	1·79	1·78	1·75	1·77	
	Mean ±0·08	1·32	1·51	1·81	1·88	..	

TABLE VIII

Treatment effects on boll weight in gm. at Convillepur

(Light sandy non-saline soil)

Dates / Nitrogen	*d1* (8/5)	*d2* (23/5)	*d3* (7/6)	*d4* (22/6)	Mean
o . . .	1·76	2·28	2·30	2·31	2·16
n . . .	2·15	2·28	2·44	2·30	2·29
Diff. ±0·087 .	0·39**	...	0·14	—0·01	...

Mean response to N=0·13**±0·043

Dates / Varieties	*d1* (8/5)	*d2* (23/5)	*d3* (7/6)	*d4* (22/6)	Mean	
289F/43 . .	2·05	2·59	2·57	2·68	2·47	±0·049
K25 . .	1·96	2·31	2·52	2·12	2·22	
Mol. 39 . .	1·86	1·94	2·02	2·11	1·98	
Mean ±0·043 .	1·96	2·28	2·37	2·30	...	

Dates (linear)=1·14**±0·19

Dates (quadratic)=—0·19**±0·043

The sandy character of the soil at Convillepur was also conductive to a well marked response to nitrogen application. On further analysis of the data it is seen that highly significant increase with nitrogen was restricted to the plots of the first sowing only. The decline in response to nitrogen with the advancing sowing dates is to be expected on light sandy soils as already pointed out in a previous contribution [Dastur and Mukhtar Singh, 1944]. It is probable that greater jassid attack on nitrogen-treated plants of the later sowings might also have inhibited any small improvement that would otherwise have occurred with N in the later sowings.

The first experiment at Lyallpur which aimed at exploring the effect of frequent irrigations in addition to that of late sowing with reference to the two varieties (4F, Mol. 39) clearly demonstrated the effectiveness of either of the two measures on a soil with a saline subsoil (Table IX). The relative importance of each measure, however, varied with the varieties. Heavy irrigation was efficacious only in the case of 4F, while late sowing helped Mol. 39 to a greater extent.

TABLE IX

Treatment effects on boll weight in gm. at Lyallpur

(Sandy loam with saline subsoil)

	Varities	4F		Mol. 39	
d2—d1 = 0·20** ± 0·033	Dates / Watering	*d1* (18/5)	*d2* (20/6)	*d1* (18/5)	*d2* (20/6)
w2—w1 = 0·22** ± 0·062	*w1*	1·60	1·85	1·41	1·68
4F—*Desi* = 0·32** ± 0·101	*w2*	2·08	2·08	1·47	1·77
		**	**		
V. D. = 0·08* ± 0·033	Diff.	0·48	0·23	0·06	0·09
W. V. = —0·138* ± 0·062	D. V. W = 0·068 ± 0·038				

TABLE X

Treatment effects on boll weight in gm. at Lyallpur

(Light sandy soil with alkaline patches)

Dates / Nitrogen	*d1* (10/5)	*d2* (28/5)	*d3* (15/6)	Mean ± 0·091	Dates / Varieties	*d1* (10/5)	*d2* (28/5)	*d3* (15/6)	Mean ± 0·038
0	1·66	1·61	1·83	1·70	4F	1·44	1·47	1·60	1·50
16 lb. N	1·60	1·65	1·84	1·70	289F/43	1·98	1·97	2·07	2·01
32 lb. N	1·67	1·76	1·82	1·75	LSS	1·89	1·83	2·05	1·92
48 lb. N	1·81	1·84	1·91	1·85	Mol. 39	1·43	1·55	1·71	1·56
Mean ± 0·019	1·68	1·71	1·86	..	Mean ± 0·019	1·68	1·71	1·86	..

The evidence furnished by the second experiment at Lyallpur (Table X) points to the conclusion already reached that the later the sowing, the better the boll size. June sowing was significantly superior to the two May sowings which did not differ among themselves. All the four varieties responded equally to late sowing. The magnitude of increase with late sowing, however, was not very high in this experiment, due to the presence of alkalinity in the surface foot in big patches over considerable area of the field. For the same reason, the effect of nitrogen which was kept as main-plot treatment was not demonstrable in this experiment.

The effects of sowing date, nitrogen and watering on yields. The results of yields under different treatments were not identical with those already discussed above for the opening of bolls, as yields depend not only on the size of bolls but also on their number. Increase in boll size is not always associated with increase in boll number. In fact, the two may even be negatively correlated, in which case quality gains at the expense of quantity.

The trends of yield under the four sowing dates were of two types. Either the linear response to dates was significant or there was a significant departure from the linear. In the latter case the combined yield of the second and the third sowings was significantly better than that of the first and the fourth. The following points should be borne in mind before considering the mean responses to dates: (1) Close spacing adopted for the fourth sowing did not prove adequate on very light sandy soils or those possessing saline patches near the surface. Consequently the boll number decreased considerably in the last sowing. (2) The inclusion of Mol. 39 in most of the experiments subdued the mean response to sowing date as all sowings under this variety behaved alike and did not show any yield trend with advance in sowing dates. (3) The American varieties also differed to the extent to which they lent themselves for late sowings. In some cases, the order of their suitability for delayed sowing was the same as the order of their resistance to jassids (*Empoasca devastans*). Since 1940-41 was a relatively wet year, jassid attack was much pronounced on some of the varieties. (4) Watering and nitrogen treatments also modified the mean response to sowing date, as May-sowings profited more by these treatments than June-sowings. These effects will be indicated by significant interactions between sowing date and other factors.

The results of the individual experiments require to be considered for a comprehensive study of the effect of sowing time and its relation to other treatments. The actual dates of sowing are given in parentheses in each case.

The results for Sargodha (Table XI) revealed that optimal values for sowing date were obtained at the third sowing in case of L S S and 4F. The yield of 289F/43, however, was maintained at a uniformly low level as far as the second week of June. The yields fell off in the case of all Americans in the last sowing. Mol. 39, on the other hand, kept up its yield at a high level over the entire sowing period. L S S gave the highest mean yield of the three Americans irrespective of sowing dates, and its superiority became more and more marked as the sowing was delayed till the optimum date.

Nitrogen increased the yield significantly on account of the sandy character of the soil under the experiment at Sargodha and the response to N varied with the varieties. They responded in the order of their yielding capacity, viz. Mol. 39 > L S S > 4F > 289F/43. The response also differed with the sowing dates. Only the first two sowings gave substantial increases in yield through nitrogen application.

TABLE XI

Treatment effects on yield (md. per acre) at Sargodha

(Light sandy and saline)

Dates / Varieties	*d1* (15/5)	*d2* (30/5)	*d3* (15/6)	*d4* (30/6)	Mean ±0·45
289F/43	5·37	5·87	5·81	2·56	4·90
L.SS	8·53	10·17	12·64	5·19	9·13
4F	7·00	8·30	8·79	3·19	6·82
Mol. 39	17·19	18·09	16·41	17·27	17·24
Mean	9·52	10·61	10·91	7·05	..

Nitrogen / Varieties	*o*	*n*	Diff. ±0·946
289F/43	4·79	5·01	0·22
L. S. S.	7·95	10·31	2·36*
4F	6·08	7·56	1·48
Mol. 39	15·24	19·24	4·00**
Mean	8·52	10·53	..

Dates / Nitrogen	*d1*	*d2*	*d3*	*d4*	
o	8·09	8·68	10·21	7·09	8·52
n	10·96	12·53	11·62	7·01	10·53
Diff. ±1·06	2·87*	3·85**	1·41	—0·08	..

Dates (linear) = —7·11** ± 2·38
Dates (quadratic) = —4·94** ± 1·06
Nitrogen = 2·01** ± 0·53
Watering = 0·65 ± 0·53

At Brucepur (Table XII) all varieties gave the highest yields under the third sowing. The yield increased rapidly with delay in sowing in L S S As increase in 289F/43 through late sowing proceeded slowly, the differences in yield between L S S and 289F/43 widened as the sowing was delayed. Beyond the third sowing, decline in yield occurred, but this decline was steeper in case of 289F/43 and is to be attributed to excessive curtailment in the

grand period of growth of this early-maturing variety. In such cases, particularly, the spacing provided turned out to be inadequate on account of the limited growth made by the plants.

TABLE XII

Treatment effects on yield (md. per acre) at Brucepur

(Sandy loam with saline subsoil)

Dates / Varieties	*d1* (8/5)	*d2* (24/5)	*d3* (8/6)	*d4* (24/6)	Mean ±0·52	Watering / Varieties	*w1*	*w2*	Diff. ±1·33
289F/43 . .	8·78	9·72	10·69	5·89	8·77	289F/43 . .	8·09	9·44	1·35
LSS . . .	9·63	12·52	15·93	10·34	12·10	LSS . .	10·94	13·26	2·32
Mol. 39 . .	24·93	24·25	25·68	22·85	24·42	Mol. 39 . .	21·81	27·03	5·22**
Mean . . .	14·44	15·49	17·43	13·02	..	Mean . .	13·62	16·58	..

Boll number per sq. yard

Mean	*d1*	*d2*	*d3*	*d4*
±2·60	71·7	65·4	66·6	47·3

Dates (quadratic) = —5·46* ±2·05

Watering = 2·96** ±1·02

N = 1·15 ±1·02

The varieties responded to watering in the order of their yield capacity, viz. Mol. 39 > LSS > 289F/43. Nitrogen did not give significant increase in yield nor did it interact with any other factor, because of the saline subsoil.

It is evident from a study of Table XIII for Convillepur (Montgomery) that quadratic response to dates was highly significant, since the central sowings were revealed to be optimum on the whole. Besides, varieties exhibited marked differential behaviour in relation to sowing date. It is remarkable that 289F/43 adapted favourably to late sowing. Mol. 39 behaved indifferently. The yield of K25 could not be maintained beyond the third sowing date and this was the direct outcome of reduction in bearing caused mainly by a heavy jassid attack on K25, as already explained. The behaviour of K25 in the Montgomery tract is analogous to that of 289F/43 at Lyallpur and Sargodha.

TABLE XIII

Treatment effects on yield (md. per acre) at Convillepur

(Light sandy soil)

Dates / Varieties	*d1* (8/5)	*d2* (23/5)	*d3* (7/6)	*d4* (22/6)	Mean ±0·36	Nitrogen / Varieties	*o*	*n*	Diff. ±0·821
89F/43 . .	12·09	16·11	16·40	12·43	14·26	289F/43 . .	13·09	15·43	2·34**
K25 . . .	10·23	12·49	10·87	4·76	9·59	K25 . .	9·44	9·74	0·30
Mol. 39 . .	22·10	24·61	20·85	22·22	22·44	Mol. 39 . .	19·55	25·33	5·78**
Mean . . .	14·81	17·74	16·04	13·14	..	Mean . .	14·03	16·84	..

No. of bolls per sq. yard

	d1	*d2*	*d3*	*d4*
Mean	68·5	63·5	61·6	46·0

Dates (linear) = —6·71* ±2·55

Dates (quadratic) = —5·83** +1·14

N = 2·81 ±0·57

The soil being light and sandy the main effect of N was significant at Convillepur. Varieties did not respond equally to nitrogen application. Maximum advantage accrued to Mol. 39, medium to 289F/43 and none to K25 (Table XIII). The order of response conformed to the order of yield performance. The failure of any increase in case of K25 on light sandy soil is explicable in terms of severe jassid attack under nitrogen treatment counterbalancing any good that would otherwise have accrued as a result of manuring.

TABLE XIV

Treatment effects on yields (md. per acre) at Khanewal

(Sandy loam with saline subsoil)

Dates / Varieties	*d1* (13/5)	*d2* (28/5)	*d3* (14/6)	*d4* (27/6)	Mean ±0·49	Nitrogen / Varieties	*o*	*n*	Diff. ±0·976
289F/43 . .	6·95	7·26	9·26	12·26	8·93	289F/43 . .	8·54	9·33	0·79
K25 . . .	9·06	10·85	11·54	11·72	10·79	K25 . .	10·40	11·18	0·78
Mol. 39 . .	21·71	22·20	22·66	25·44	23·00	Mol. 39 . .	21·12	24·87	3·75**
Mean . . .	12·58	13·44	14·48	16·47	..	Mean . .	13·35	15·13	..
	d1	*d2*	*d3*	*d4*					
w1 . . .	11·05	12·09	14·02	16·11	13·32	Dates (linear) = 12·73** ±2·46			
w2 . . .	14·10	14·79	14·93	16·83	15·16	N = 1·77** ±0·55			
Diff. ±1·10 .	3·05**	2·70*	0·91	0·72	..	W = 1·84** ±0·55			

The effect of late sowing was the most marked at Khanewal (Multan) where the relation between yield and sowing date was positive and linear (Table XIV). The yield rose progressively with delay in sowing in all the varieties bringing out an optimum at the last date. The magnitude of increase was also substantial.

The response to nitrogen application at Khanewal confined itself only to the *desi* variety, which gave the maximum yield on the average. The Americans failed to respond on account of salinity in the soil. Response to watering was recorded and it declined in magnitude with the delay in sowing (Table XIV).

The experiment designed to study the effect of more frequent irrigations and late sowings at Lyallpur (Table XV) established the need for more waterings at fruiting. Early-sown 4F profited the most in conformity with the previous experience.

Substantial increases in yield, through nitrogen applications were recorded on the light sandy soil under the second experiment at

TABLE XV

Treatment effects on yields (md. per acre) at Lyallpur

(Sandy loam soil with saline subsoil)

Varieties	4F		Mol. 39		
Dates / Watering	*d1* (18/5)	*d2* (20/6)	*d1* (18/5)	*d2* (20/6)	
w1 . . .	11·62	13·16	18·91	20·67	C = —0·39 ±1·16
w2 . . .	19·97	17·96	22·77	25·88	D = 1·10 ±0·83
					W = 5·55** ±0·92
					V = —6·38** ±1·16
Diff. . . .	8·35	4·80	3·86	5·21	D. V. W. = 1·23* ±0·45

Lyallpur (Table XVI). The effectiveness of nitrogen did not fall off in the higher doses. The highest dose, of course, was only 48 lb. N per acre. The last sowing was less responsive to nitrogen than the first two, which benefited to the same extent practically.

The last sowing date proved optimum at lower levels of nitrogen (o, 16 lb. N) while the central sowing gained importance at higher levels (32 lb. N, 48 lb. N). The effect of sowing time also varied with the varieties, 4F and LSS responding favourably to delay in

TABLE XVI

Treatment effects on yield (md. per acre) at Lyallpur

(Light sandy soil with alkaline patches)

Dates / Varieties	*d1* (10/5)	*d2* (28/5)	*d3* (15/6)	Mean ±0·239	Dates / Nitrogen	*d1* (10/15)	*d2* (28/5)	*d2* (15/6)	Mean ±0·842
4F . . .	7·15	7·80	8·78	7·91	Control . .	7·90	8·40	9·27	8·52
289F/43 . .	9·40	9·49	7·52	8·80	16 lb. N . .	8·98	9·58	9·99	9·52
LSS . . .	9·72	11·27	10·70	10·56	32 lb. N . .	10·64	11·94	11·43	11·34
Mol. 39 . .	14·53	15·60	16·01	15·38	48 lb. N . .	13·27	14·24	12·30	13·27
Mean ±0·188 .	10·20	11·04	10·75	..	Mean ±0·188 .	10·20	11·04	10·75	..

sowing. As at Brucepur, LSS showed the best performance amongst the Americans under each sowing individually, and especially so under the later sowings.

1941-42

Similar effects of late sowing, as discussed in the preceding pages, with respect to the opening and the yields of American cottons, were revealed by multiple-factor experiments conducted during 1941-42. These experiments were laid out at the Military Farm, Okara, B.C.G.A. Farm, Khanewal, the Departmental Agricultural Farms at Montgomery and Multan, and S.B.S. Ujjal Singh's Farm at Mian Channu. June sowings gave higher boll weights than May sowings irrespective of the varieties. The yield results were also favourable. It is not necessary to discuss the results of the individual experiments in detail here, but a few interesting features merit consideration. A new promising strain, 289F/124, evolved by the Cotton Research Botanist, Lyallpur, for the dry districts of the Punjab, was included along with other varieties in some of the experiments. It can be seen from Table XVII that this variety behaved remarkably well under late sowing both at Montgomery and Multan. It is necessary to point out that at Lyallpur 289F/124 is generally a failure when sown in June because of reduction in bearing caused by subnormal growth and jassid attack and inability of this variety to cover the soil surface under these conditions.

TABLE XVII

Effect of late sowing in relation to variety on boll weight and yield

	Montgomery (1941-42)						Multan (1941-42)		
	Boll weight (gm.)			Yield (md. per acre)			Yield (md. per acre)		
Dates / Varieties	*d1* (15/5)	*d2* (8/6)	*d3* (24/6)	*d1* (15/5)	*d2* (8/6)	*d3* (24/6)	*d1* (19/5)	*d2* (6/6)	*d3* (24/6)
289F/43	1·81	2·03	2·09	10·11	10·98	9·75	11·65	12·45	13·49
289F/K25	1·22	2·16	1·91	7·73	10·11	7·87	10·04	12·12	12·66
289F/124	1·23	2·28	2·01	9·19	14·71	11·39	9·52	11·99	16·34
Mean .	1·42	2·16	2·00	9·01	11·93	9·67	10·40	12·19	14·61
S.E.		±0·0596			±0·42			±0·598	

The weather conditions in Multan and Montgomery are generally different from those at Lyallpur and were specially so in the year under report (1941-42). The months of September and October were characterized by unusual spells of higher temperatures than normal in the south-western district so much so that *tirak* appeared in a serious form in the early sowings under adverse soil conditions, and even spread to areas mediumly saline in the subsoil. Lyallpur, however, experienced mild temperatures and abundant rains during

August and September, and October too was not unusually warm. Owing to the favourable weather, the May sowings in the experiments at Lyallpur matured their bolls normally, in spite of the saline subsoil. This resulted in the absence of any increase in yield due to deferred sowing even though the variety used was 4F (Table XVIII). It is noteworthy, however, that the yield did not fall under June sowing. Similarly it has been observed that on rich non-saline lands where the opening of bolls is normal irrespective of sowing date, June sowing is as good as May sowing, provided the spacing is close enough under the former.

TABLE XVIII

Effect of late sowing on 4F at Lyallpur (1941-42)

(Sandy loam soil with saline subsoil)

	d1 (21/5)	*d2* (23/6)	Remarks
Yield (md. per acre)	18·16	18·65	Differences non-significant
Boll weight (gm.) .	2·70	2·75	

C. Extensive trial of late sowing on a commercial farm (1940-41)

To set up late sowing on a practical basis it was necessary to test it on a field scale. B.C.G.A. Farm, Khanewal, was the first commercial farm that took the lead in this direction and offered cooperation to try out this measure extensively. The sowings on this farm used to start in the first week of May and finished by the end of this month. The crop was frequently subject to intense *tirak* and the yields were generally much below expectation. Since 1940, May sowings have been practically abandoned in favour of June sowings, with encouraging results. A record yield of 15 md. per acre was obtained over an area of 1,500 acres in 1940-41. In the following season, in spite of the very unfavourable weather at boll development, in the form of a hot and dry spell, from the end of September to the middle of October, damaging the crops in the districts of Montgomery and Multan, the average yield at the Khanewal Farm was 10 md. per acre. In 1942-43, the sowings were again done according to the schedules (given later) but due to unusual rains in the first week of July, some of the fields had to be resown and sowings completed by the middle of July. Nevertheless, the average yield was 16½ md. per acre.

To get an idea of the actual benefit accruing from the adoption of this measure, a simple but replicated sowing-date experiment with K25 variety was also arranged at the B.C.G.A. Farm, Khanewal, in 1940 and repeated in the two succeeding seasons. Twelve strips of land of two acres each under uniform cropping were selected each year, and the choice was extended over a number of squares of a *chak* which was different in different years. Each strip was divided into four half-acre plots, and the four dates of sowing were allocated at random to them. Each plot was picked and weighed separately so that the result could be statistically analysed. There was remarkable similarity from year to year, in the yield trend of the different sowings, in spite of the wide variations in the level of yields and the character of the soil and the season. June sowings were consistently better than extreme sowings and the highest yield was obtained from the crop sown about 20 June (Table XIX).

DISCUSSION

In addition to ameliorating *tirak*, the yield of *kapas* can also be increased and maintained by June sowing, provided closer and closer spacing is adopted with advancing sowing dates in June and due consideration is given to the choice of variety. The relation of spacing with sowing date has been fully discussed in the

TABLE XIX

Effect of late sowing on the yield of cotton at the B. C. G. A. Farm, Khanewal, for three successive seasons (1940-42)

(Yield in maunds per acre)

Year	Site	Area	*d1* (19-22 May)	*d2* (4-7 June)	*d3* (19-22 June)	*d4* (5-7 July)†	S. E.
1940-41 . .	Chak 75	24 acres	12·62	14·48	16·10	14·92	±0·62
1941-42 . .	Chak 83	24 acres	5·38	6·47	7·06	5·77	±0·406
1942-43 . .	Chak 81-82	20 acres	9·50	14·87	15·49	8·58†	±0·912

† Resown on 15 July due to rains

previous contributions [Dastur and Mukhtar Singh, 1942; 1943] and is in accord with the experience of other workers on cotton in the Sudan [Gregory *et al.*, 1932; Lambert and Crowther, 1935]. Schedule A gives an idea of the changing seed rates and spacings with advancing weeks in sowing period, and has been prepared from practical point of view to suit the Punjab conditions.

Schedule A

Date of sowing	Seed rate to be used per acre	Distance to be kept between rows	Distance to be kept between plants
25—31 May . . .	7—9 sr.	2½ ft. to 3 ft.	1½ ft.
1—7 June . . .	8—10 sr.	2½ ,,	1¼ ,,
8—15 June . . .	10—12 sr.	2 ,,	1¼ ,,
16—23 June . . .	12—14 sr.	2 ,,	1 ,,
24—30 June . . .	14—16 sr.	1½ ,,	9 in.

The differential behaviour of variety with sowing date is the outstanding feature of this investigation. 289F/43 variety in the Lyallpur and Sargodha districts and K25 in the Montgomery district do not do well when sown after 15 June on account of a marked decrease in their boll number under these conditions. K25 and 289F/124 behave still worse under June sowings at Lyallpur. On the other hand, LSS in Lyallpur and Sargodha, 4F in Lyallpur, 289F/43 in Montgomery and Multan, and 289F/K25 and 289F/124 in Multan respond favourably to delay in sowing. These varieties are popular with the cotton growers in their respective localities and this renders the adoption of late sowing in general practice easy. The superiority of a variety adapted to a particular tract becomes better and better marked as sowing is delayed till the optimum date which is usually in the second week of June. Under earlier sowing, however, the Americans do not differ so widely.

The cause for the better adaptability of certain varieties to late sowing is to be sought in their ability to make sufficient growth so that the bearing capacity does not suffer appreciably. Besides, as already pointed out in a previous contribution [Dastur and Mukhtar Singh, 1942], the varieties that are susceptible to jassids, e.g. K25, 289F/124, have an earlier optimum under conditions inducing jassid attack, as compared with others that are relatively jassid resistent, e.g. LSS, 289F/43 and 4F. Where jassid attack is non-existent, K25 and 124F do admirably well under late sowings.

A cultivator is unable to sow all his cotton in a single day. Sowings have got to be distributed over two, three or even four weeks, depending upon the availability of water, sowing facilities and method of sowing. In practice, therefore, we have to decide upon the optimum sowing period rather than the optimum sowing date. Thus sowings must extend on either side of the optimum date as revealed by experiments, and varieties chosen should be appropriate as they vary in their suitability for late sowing.

The absolute range of sowing period for different localities is different, even if the right variety is used in the right place. As the primary reason for advocating late sowing is to maintain water balance of the plant under conditions of physical or physiological drought or both, it is natural that such a practice becomes indispensable in drier parts, viz. Multan and dry parts of Montgomery. In such places the sowings can extend as far as the beginning of July, because of the long spell of hot and dry weather which proves disastrous for early sowings. In districts where wet summers are more frequent, e.g. Sargodha and Sheikhupura, delay beyond the middle of June in years of heavy rainfall is exposed to danger of jassids. But early sowings have got to be avoided on account of danger of *tirak* in certain years and under certain soil conditions. At such places the rule should be to start late, sow quick and plant thick. For localities such as Lyallpur and Jhang which occupy intermediary position as regards the distribution of rain, the sowing period also lies mid-way between the two extremes. Schedule 'B' gives in a concise form an idea of the optimum sowing periods based on the above considerations.

In the early years of introduction of American cottons in the Punjab, the general sowing time was the month of March, which was then shifted to April gradually. In later years the month of May has been recognized to be the

Schedule B

Districts	Best sowing period	Variety
Sargodha, Sheikhupura	25 May—15 June	LSS
Lyallpur, Jhang	25 May—20 June	LSS and 4F (43F, if sown, should be completed before 15 June)
Montgomery	25 May—25 June	K25 and 43F (K25 should not be sown after 15 June)
Multan	1 June—5 July	K25, 43F, and 124F

Note.—Light sandy soils or soils of low fertility should, in practice, be sown in the first fortnight of the sowing periods recommended in the schedules, as further delay in sowing on such lands is apt to increase boll size at the cost of boll number and thus cause reduction in yield

optimum period. As a result of the recent investigations into the *tirak* problem the superiority of June sowings has definitely been brought out. It can thus be conceived why failure years concentrated in the 10-year period 1919-1928 and the crops failed miserably in 1919, 1920, 1921, 1926, 1927 and 1928.

It appears that American cottons, to start with, came to be sown about the same date as was prevalent in case of the indigenous short-stapled cottons. The sowings were then early and seem to be induced by the availability of water at the termination of the *rabi* season. Besides, the abundant growth made by such sowings gave the misleading impression of correlated high yields. These factors, rather than any direct evidence, popularized the tendency for early sowings. The practice may not have been as bad in the case of *desi* as of Americans because the former are able to mature their bolls and maintain yields over a wide range of sowing period. The Americans, with the sowings in vogue at that time, undoubtedly, suffered greatly under certain soil and climatic conditions.

The interplay of soil conditions with the weather factors governs the intensity and spread of *tirak* in a particular year. Under the influence of favourable weather, the crop on certain fields potentially subject to *tirak*, may actually escape its onslaught, even though sown in May. There can thus be wide variations in the yield of cotton on such fields from year to year. The benefit that can be expected to accrue from late sowing, will like-wise vary. The usefulness of this measure on a particular soil in a particular year will be great or small depending upon the decrement in the boll weight of the early-sown crop from the normal.

The differential response of varieties to nitrogen is another important finding of this experiment. It is noteworthy that the response order of the varieties is also the order of their yielding capacity. Similar relation has been recorded for varieties in Egypt by Crowther *et al.* [1937].

Desi (Mol. 39) responds the most everywhere. LSS is seen to respond better than 289 F/43 in Lyallpur and Sargodha. 289F/43 is better suited for manuring than K25 in Montgomery on account of the latter's known susceptibility to jassids, particularly under N-fed conditions. It is, however, possible that 289F/43 and K25 may not differ so widely in their response to nitrogen in a non-jassid year.

Watering has been effective in most of the experiments where salinity was present in the subsoil. As with nitrogen, the response to water has been great or small in the different varieties according to their yield.

The declining responses to nitrogen and water with advancing sowing dates suggest a rational discrimination in the use of additional water or nitrogen if available. The first sowings within the sowing range stated in Schedule 'B', should receive preferential treatment for extra watering on fields with saline subsoils, and for nitrogen on light sandy non-saline lands.

The differential behaviour of the three ameliorative treatments under the three soil types can be condensed in the form of a table (Table XX) which is self-explanatory.

Obviously, the maximum benefit can only be derived when the right remedy is applied in the right place. It is not normally possible for a *zamindar* to distinguish the soil conditions causing *tirak*. Besides, soils with saline or normal subsoil are intermingled. The practice of late sowing obviates the study of soil conditions and is, therefore, of wider applicability. As the adoption of this measure involves no extra cost, any increase in yield, great or small, is a net gain.

TABLE XX

Relative magnitude of the ameliorative effect of water, nitrogen and late sowing on the three soil types

	Sandy loams with saline subsoil	Light sandy and saline	Light sandy
Extra water . . .	High response on opening and yield	Medium response on opening and yield	Low response on opening and yield
Nitrogen	No response on opening and yield	No response on opening but medium to low response on yield due to an increase in boll number	High response on opening and yield
Late sowing with close spacing and under ordinary water supply	High response on opening and yield	High response on opening and yield	High response on opening and low to medium response on yield

SUMMARY

This paper embodies the results of numerous multi-factor experiments in relation to *tirak* disease of cotton conducted in the different cotton-growing tracts of the Punjab over a number of years with the commonly-cultivated varieties.

Applications of nitrogen and extra water are specific remedies. Extra water at the fruiting stage ameliorates *tirak* and gives higher yields of *kapas* on soils with saline subsoil, where nitrogen application is totally ineffective.

Application of nitrogen is highly successful in reducing *tirak* and raising yields on light sandy non-saline soils, where the response to heavy watering is meagre.

On soils which are not only sandy and deficient in nitrogen but are also saline or alkaline in the subsoil, the application of nitrogen does not improve opening of bolls even though it raises the yield through more profuse bearing.

June sowing is a common ameliorative measure irrespective of the *tirak*-promoting soil conditions. The commonly-cultivated American cottons are prone to *tirak* when sown in May, but they improve in opening when sown in June. The yield results are also favourable, provided the necessity of close spacing for late sowing is correctly appreciated.

As it is extremely difficult for a *zamindar* to distinguish the soil conditions causing *tirak* the adoption of late sowing as a general measure is of great practical value.

Two schedules have been prepared for the guidance of the cultivators on the basis of experimental results. Schedule A gives an idea of the changing seed rate and spacing with advancing dates of sowing. Schedule B furnishes particulars as to the optimum sowing periods for the commonly-cultivated varieties in each district.

A large number of big as well as small cotton growers have recently based their practice on the above recommendations with encouraging results.

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REFERENCES

Crowther, F., Tomforde, A., and Mahmoud, A. (1937). Experiments in Egypt on the interaction of factors in crop growth, 8. Manuring of cotton in Egypt, *Bull. No. 32. Royal Agri. Soc., Egypt*

Dastur and Mukhtar Singh (1942). Studies in the periodic partial failures of the Punjab-American cottons in the Punjab, VII. Amelioration of *tirak* on soils with saline subsoils (sandy loams). *Indian J. agric. Sci.* **12**, 679-95

——————————(1944). Studies in the periodic partial failures of the Punjab-American cottons in the Punjab, X. The interrelation of sowing date, nitrogen, water supply and spacing on growth and yield of 4F cotton. *Indian J. agric. Sci.* **14**, 18—29

Gregory, F. G., Crowther, F., and Lambert, A. R. (1932). The interrelation of factors controlling the production of cotton under irrigation in the Sudan. *J. agric. Sci.* **22**, 617

Lambert, A. R., Crowther, F. (1935). Further experiments on the interrelation of factors controlling the production of cotton under irrigation in the Sudan. *Emp. J. Expt. Agri.* **3**, 276

ON PHOTOPERIODIC EFFECT OF JUTE PLANTS

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(With Plates IV and V)

The work of Garner and Allard [1920; 1923] and of Tincker [1925; 1928; 1929] showed that plants in their behaviour towards the length of light exposure, arrange themselves into three general groups according to the effect of the treatment upon the time of flowering: (*a*) those species and varieties which are apparently little affected in their time of flowering by the duration of the exposure to light—called '*neutral*' *plants* by some; (*b*) those plants which are caused to flower by the action of short days—called '*short day*' *plants*; and (*c*) those plants which are forced into flowering through the action of long days—called '*long day*' *plants*.

Lysenko showed that in the course of development the plant requires a different set of conditions for the different phases, an early one of which is the definite temperature requirement called the 'Vernalization stage' or 'Thermo stage'. This 'Thermo stage' is followed by a second stage in which the plant requires a certain length of day called 'Photo stage' (*Phasic development of plants*, 1935). Thus Lysenko's view of Photoperiodism is that the vernalization stage has to be followed by a 'Photo stage' for which a certain length of day is necessary. When this stage is completed the daily period of illumination no longer influences the time of flowering.

In India the influence of the length of the day on the course of development specially on the time of flowering has been recorded by Sen and Chakrabarty [1942] on mustard, Pal and Murthy [1941] on gram and wheat, Alam [1937] and Sircar [1942] on rice and Rhind [1935] on sesamum.

This paper contains the results of preliminary investigations on how far the length of the day is of influence on the growth and development of jute plants.

Experimental procedure

Corchorus Capsularis (D. 154) and *C. Olitorius* (Chinsura Green) the two recommended strains for the low and high lands respectively were used for the experiments. Seeds were obtained by the courtesy of the Director, Jute Agricultural Research Laboratories, Dacca.

On 20 April 1943 dry seeds were sown in earthenware pots 13 in.×13 in. containing well manured soil, at the rate of 40-50 seeds per pot at four different places equidistant from the centre and the wall of the pot. As the seedlings developed they were removed from time to time keeping four best plants in each pot, and were equally watered regularly except on rainy days. Experiments were devised in consultation with the Statistical Laboratory, Presidency College, Calcutta. For sufficient number of replicates 15 pots were taken for each species with 4 plants per pot, the pots being divided into three sets of 5 pots each one set as control and the other two sets were exposed to two types of short day treatments. In the first treatment (Treatment I) the pots were removed to a specially constructed dark chamber in the field at about 4 p.m. and brought back outside at dusk from 25 April 1943, i.e. 5 days after sowing when the seedlings were distinct and exposed to this treatment for 60 days. In the second treatment (Treatment II) the exposure to similar treatment as above commenced after 30 days of growth in normal conditions and continued for 60 days as in the previous case. Thus the short day treatment meant an exposure shorter by 3 hr. approximately than the full day length which varied between 12 hr. 39 min. and 13 hr. 27 min. during the period. The treated plants were otherwise exposed to exactly the same conditions as the control.

To study the effect of treatments on the growth and development of the plants, the following measurements were recorded every week commencing from, when the plants were 30 days old till the maturity of the first fruit. Growth, however, continued slowly even after this.

(1) Height of the stem in cm.

(2) Number of nodes of the stem excluding undifferentiated nodes of the extreme apex.

(3) Number of leaves on the main stem. This included the newly unfolded immature leaves of the apical rosette.

(4) Number of leaves shed from the base of the stem. From these counts the life of the different leaves, the total number of leaves present on the main stem for active photosynthesis can be calculated.

In all the leaf counts the pairs of the cotyledonary leaves were taken as one leaf.

(5) Number of branches more than 5 cm. in length. They were counted under three heads, viz. (*a*) 5 cm. and more, (*b*) 15 cm. and more, and (*c*) 30 cm. and more.

FIG. 1. Fifty-five days old *C. Capsularis* plants
(B16) Control—Vegetative ;
(B10) Treatment I—Fruiting

FIG. 2. Fifty-five days old *C. Olitorius* plants
(B32) Control—Vegetative ;
(B22) Treatment I—Fruiting

FIG. 1. 120 days old *C. Capsularis* plants
(a) Treatment I with over-ripe fruits;
(b) Treatment II with ripe fruits;
(c) Control with flower buds

FIG. 2. 120 days old *C. Olitorius* plants (a) Treatment I with over-ripe fruits; (b) Treatment II with ripe fruits; (c) Control with flower buds

When the plants in a set began to flower, they were examined regularly and the time of the initiation of flower buds, fruits and maturity of fruits were noted for each plant. These data were recorded on the following basis:

(*a*) Differentiation of morphologically visible flower buds were taken as date of flowering.

(*b*) Differentiation of morphologically visible first fruit was taken as the date of fruiting, and

(*c*) Ripening of the first fruit was taken as the maturity of fruit.

In every case data were recorded for all the plants separately and the mean values are recorded in the different tables given below.

The mean time required for flowering and fruiting and the differences between the control and treated plants are given in Table I.

TABLE I

Time of flowering and fruiting

Treatment	Mean date of flowering in days	Earliness from control in days	Time of flowering in days after commencement of treatment	Mean date of fruiting in days	Earliness from control
C. Capsularis					
Treatment I	32·6	81·5	27·6	47·6	87·0
Treatment II	47·4	66·7	17·4	60·4	74·2
Control	114·1			134·6	
C. Olitorius					
Treatment I	27·8	98·1	22·8	36·0	99·4
Treatment II	44·4	81·5	14·4	56·3	79·1
Control	125·9			135·4	

It is seen that the plants exposed to short days flowered and fruited much earlier than the control and of the two treatments, plants of Treatment I flowered and fruited earlier than those of Treatment II. Plants of Treatment II responded much earlier after commencement of treatment than those of Treatment I.

It is found that a great development of a branch from an axiliary bud near the apex of the stem leading to the look of an apical split is associated with the initiation and production of flower buds, flowers and fruits.

Mean heights of plants in different treatments are given in Table II.

It is found that the treated plants which are seen to flower much earlier (Table I) also remained short. Thus earliness of flowering due to short day treatment is associated with checked growth (vegetative) in length. It is seen that of the two treatments plants of Treatment I remained shorter than those of Treatment II.

It is found that the apical branch grows longer and longer almost equally as the main stem at the apical portion, which now grows in an inclined manner (pronounced in *C. Olitorius* and less in *C. Capsularis*), and thus these two subtend an angle at the apex giving the appearance more or less of a Y type, the angle being more or less 90° in *C. Capsularis* and about 145° in *C. Olitorius*.

The mean number of total nodes at different stages are given in Table III.

It is seen that the number of nodes is much greater in the control than in the treated ones and between the two treatments, plants of Treatment II had a larger number of internodes than those of Treatment I.

The number of branches separately under 5 cm. and more, 15 cm. and more and 30 cm. and more are recorded in Tables IV and IV-A.

It is seen that the treated plants developed a greater number of branches than the control under all the three heads in *C. Capsularis*, where the difference between the two treatments is that the total number of branches 5 cm. and more is greater in Treatment II, whereas those of 15 cm. and more are distinctly greater and of 30 cm. and more slightly greater in Treatment I.

Thus *C. Capsularis* of Treatment I developed a larger number of branches and became more bushy than those of Treatment II which developed a larger number of shorter branches.

In *C. Olitorius* branches began to be produced first in Treatment I, then in Treatment II, much earlier than the Control. These branches slowly increased in length and at the time of maturity of fruit, the plants of Treatment I (65 days after sowing) had the largest number of branches. In the long run, however, control plants produced the largest number of branches of both 5 cm.-15 cm. or 15 cm.-30 cm., but there was no appreciable difference with branches more than 30 cm. Plants of Treatment II produced lesser number of smaller branches.

The total number of leaves on the main stem and those dead from base as the plant grew are recorded in Tables V and VI.

Table II

Height in cm.

	Days after sowing																
	30	37	44	51	58	65	72	79	86	93	100	107	114	121	128	135	142
C. Capsularis																	
Treatment I .	35·81	63·50	83·57	97·79	105·86	108·20											
Treatment II .		72·39	99·06	119·13	138·68	153·67	156·21	157·48	150·48	157·99							
Control . .	44·96	73·41	100·58	122·68	140·46	157·48	169·16	183·89		209·04	223·52	238·76		260·86	269·24	284·48	
C. Olitorius																	
Treatment I .	18·54	39·62	54·88	69·31	78·99	85·60											
Treatment II .		48.26	72·90	95·00	117·86	128·27	132·08	135·64	140·22								
Control . .	30·23	54·10	82·04	108·46	132·33	160·02	184·30	201·93		241·05	252·98	270·51		286·42	318·52	327·66	

Table III

Number of nodes

	Days after sowing																
	30	37	44	51	58	65	72	79	86	93	100	107	114	121	128	135	142
C. Capsularis																	
Treatment I .	12·2	19·9	23·3	28·1	29·6	30·0											
Treatment II .		18·5	25·4	36·2	39·5	42·6	43·7	44·7	46·5	47·2							
Control . .	12·2	18·5	23·2	31·3	35·2	40·8	45·0	51·8	...	58·3	64·1	69·1	...	77·8	79·2	82·4	85·4
C. Olitorius																	
Treatment I .	8·4	12·2	16·0	23·4	26·3	28·5											
Treatment II .		13·5	20·5	33·5	37·6	39·5	41·3	43·3	44·7								
Control . .	9·8	14·8	22·9	30·0	37·7	44·1	48·4	58·1	...	67·9	72·9	78·6	...	84·3	95·3	101·3	106·3

TABLE IV

Number of branches

(*C. Capsularis*)

	Days after sowing																
	30	37	44	51	58	65	72	79	86	93	100	107	114	121	128	135	142
CONTROL																	
Branches 5 cm. or more		0·7	2·6	1·6	1·9	2·5	2·5	2·2	...	2·1	1·8	2·0	...	2·2	3·6	5·2	7·5
Branches 15 cm. or more			0·35	0·80	0·78	0·89	0·74	0·82	...	0·83	0·83	0·88	...	0·86	1·7	3·2	5·0
Branches 30 cm. or more			0·15	0·25	0·25	0·25	0·25	0·36	...	0·30	0·50	0·55	...	0·32	0·53	1·0	2·4
TREATMENT I																	
Branches 5 cm. or more		*	13·4	14·1	14·4	14·3											
Branches 15 cm. or more			1·4	8·9	8·9	9·8											
Branches 30 cm. or more				2·4	2·7	2·9											
TREATMENT II																	
Branches 5 cm. or more		0·6	1·9	2·1	7·4	15·2	13·6	16·4	19·3	19·5							
Branches 15 cm. or more			0·5	0·9	2·2	3·9	3·7	4·8	6·0	6·5							
Branches 30 cm. or more			0·2	0·3	0·5	0·9	1·9	2·3	2·4	2·5							

* Total No. of branches was not recorded

TABLE IV-A

Number of branches

(*C. Olitorius*)

	Days after sowing																
	30	37	44	51	58	65	72	79	86	93	100	107	114	121	128	135	142
CONTROL																	
Branches 5 cm. or more						0·1	0·6	0·9	...	1·6	1·7	2·9	...	6·9	7·1	10·0	13·0
Branches 15 cm. or more							0·1	0·3	...	0·5	0·4	0·4	...	0·93	1·6	2·8	5·0
Branches 30 cm. or more														0·1	0·3	0·7	1·7
TREATMENT I																	
Branches 5 cm. or more		*	3·9	3·0	5·2	5·0											
Branches 15 cm. or more			0·9	2·1	2·1	2·5											
Branches 30 cm. or more				1·0	1·1	1·4											
TREATMEET II																	
Branches 5 cm. or more				1·8	3·5	3·5	3·2	3·4	3·5								
Branches 15 cm. or more				0·7	2·0	2·4	2·6	2·7	2·8								
Branches 30 cm. or more					1·8	1·9	1·8	1·8	1·8								

* Total No. of branches was not recorded

TABLE V

Total leaves produced on the main stem

	Days after sowing																
	30	37	44	51	58	65	72	79	86	93	100	107	114	121	128	136	142
C. Capsularis																	
Treatment I .	16·2	20·2	23·0	28·7	30·4	31·0											
Treatment II .		20·7	29·7	37·7	40·3	43·0	44·3	44·7	45·3	45·4							
Control . .	16·5	21·2	27·7	35·3	40·6	45·5	49·8	55·4	...	64·3	69·1	74·0	...	80·05	81·1	83·8	87·0
C. Olitorius																	
Treatment I .	12·4	13·0	20·2	25·1	27·8	29·4											
Treatment II .		16·9	24·6	34·2	37·9	40·0	42·0	44·6	47·1								
Control . .	14·0	19·1	24·1	35·1	42·7	49·2	52·8	59·5	...	71·8	78·0	83·3	...	94·8	98·3	103·4	108·3

TABLE VI

Total leaves dead from base

	Days after sowing																
	30	37	44	51	58	65	72	79	86	93	100	107	114	121	128	136	142
C. Capsularis																	
Treatment I .	1·3	1·3	2·2	9·0	13·9	19·0											
Treatment II .		1·1	2·2	6·0	7·8	17·4	23·8	28·4	38·3	41·7							
Control . .	1·1	1·3	2·2	4·4	6·7	9·1	11·1	14·8	20·6	23·8	27·2	...	...	43·9	51·6	56·7	63·1
C. Olitorius																	
Treatment I .		0·7	1·2	7·0	8·7	12·0											
Treatment II .		0·7	1·6	8·7	10·4	15·5	18·7	23·3	32·7								
Control . .	0·2	1·4	2·1	7·4	11·5	15·6	18·4	21·3	...	32·1	39·6	...	...	59·1	60·6	68·8	78·3

It is seen that the total number of leaves is much greater in the control than in the treated ones and there were more leaves developed on the plants of Treatment II than those of Treatment I.

Regarding the shedding of leaves, it is found that in *C. Capsularis* plants of Treatment II shed the largest number, second came the controls and last those of Treatment I, and in *C. Olitorius* the controls shed the most, next came plants of Treatment II and last those of Treatment I.

It should however be remembered that the total height, and number of internodes were much greater in the controls.

By following the course of developmental changes studied under different heads by weekly measurements it is seen that the stages at which the well marked differences between the controls and treated ones mentioned above began to be evident are as follows: (*a*) Height—from the time of the initiation of fruits, (*b*) Nodes—from the time of the initiation of fruits, (*c*) Branching—rapid development after flowering, (*d*) Leaf—from the initiation of fruits, and (*e*) shedding of leaves—after setting of fruits. Thus the modifications undergone by the plants under short day treatments are associated with the onset of flowering and fruiting.

Discussion

From the results of the experiments both the species of Jute seems to come under '*short day*' *plants*. The plants show a remarkable earliness of flowering associated with a remarkable modification of the vegetative growth under short day treatments as a result of which the plants remain shorter and become bushy. But from the experiment and results nothing can be said about the critical light period, critical duration of exposure to short day treatment and whether there is Photoperiodic Induction in the plant. It is, however, clearly seen that in the '*short day*' treated plants the sexual phase which sets in earlier continues vigorously in the production of flowers and fruits at the cost of vegetative growth which is considerably checked.

Regarding the significance of the photoperiodic effect mentioned for economic utility, earliness of flowering and checked vegetative growth will be of no use so far as the yield of fibre is concerned. But it can be useful for breeding experiments where it will be possible to study more than one generation during one season, and to seed farms for raising more than one generation in one season. The results also show a possibility of the vegetative stage being lengthened by long day treatments in which case it becomes of utility even in connection with fibre production of the plant.

Summary

1. Two species of jute plants *C. Capsularis* (D154) and *C. Olitorius* (Chinsura Green) were grown in pots and exposed to a daily light period shortened by 3 hr. at two stages, (*i*) from the beginning, after germination, and (*ii*) when the plants were 30 days old, till flowering and fruiting.

2. Both the species responded to treatment by early flowering and fruiting over the control, treatment from the beginning being more effective.

3. Early induction of sexual phase greatly modified the course of vegetative development and response in this respect being more pronounced in the first treatment.

4. Response to short day treatments resulted in a lower height, lower number of nodes, lower number of leaves, greater number of branches, smaller diameter of the stem and thus in shorter and bushy plants.

5. The response in vegetative development like height, number of nodes, leaves, and branches began to be evident from the time of flowering and fruiting.

REFERENCES

Alam, M. (1937). *Proc. 3rd Meeting Crops and Soil Wing Agri. and Animal Husbandry, India*

Garner, W. W. and Allard, H. A. (1920). *J. agric. Res.* 354

——————————————— (1923). *J. agric. Res.* 871

Pal, B. P. and Murthy, G. S. (1941). *Indian J. Genetics and Plant Breeding* 61

Rhind, D. (1935). A note on photo-periodism in Sesamum. *Indian J. agric. Sci.* **5**, 729-36

Sen, B. and Chakrabarty, S. C. (1942). Studies in vernalization of mustard. *Indian J. agric. Sci.* **12**, 1-34

Sircar, S. M. (1942). *J. Indian Bot. Soc.* **21**, 41

Tincker, M. A. H. (1925). *Ann. Bot.* 721

——————————————(1928). *Ann. Bot.* 101

——————————————(1929). *J. Royal Hort. Soc.* 354

Vernalization and phasic development in plants (1935). —*Bull. Imp. Bur. Plant Genetics*

STUDIES ON BASE EXCHANGE

II. A COMPARISON OF DIFFERENT METHODS OF ESTIMATING BASE-EXCHANGE CAPACITIES AND OF LIME REQUIREMENT OF HYDROGEN CLAYS, ACID SOILS* AND PARTLY AND COMPLETELY DESATURATED SOILS†

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(With two text-figures)

The variations in the total acid of hydrogen clays estimated by different methods are controlled by the *p*H and two types of cation effects [Mukherjee, Mitra and Mukherjee, 1937 ; Mitra, Mukherjee and Bagchi, 1940 ; Mitra and Mitra, 1940 ; Mukherjee, Mitra, Mukherjee and Chatterjee, 1942 ; Mukherjee and Mitra, 1942]. The *p*H effect is generally recognized but its nature is not clearly defined. It is illustrated by the continued buffering in the reaction between hydrogen clays and alkalis showing that more and more acid is neutralized by the base as the *p*H rises. The cation effect is illustrated by the following results : The b. e. c. calculated from the titration curves with different bases at a fixed *p*H, e.g. 7·0, decreases in the order Ca $(OH)_2$> $Ba(OH)_2$> NaOH. The effects of the various cations are in the order Ca^{++}> Ba^{++}> Na^{+}. This is in violation of the usual lyotrope series and has been termed the 'Irregular' or 'Specific cation effect'. When a neutral salt is added to a hydrogen clay a considerable amount of titratable acid is found in the supernatant liquid. Using a fixed concentration of different salts having a common anion which does not enter into chemical reaction with the hydrogen clay the total acid of the supernatant liquid has been found to decrease in the order Ba^{++}> Ca^{++}> Na^{+}. This order illustrates what has been termed the 'Regular cation effect' in the sense that the relative effects of the cations are in agreement with the lyotrope series. It is, however, to be noted that in the case of cations like Ca^{++} or Ba^{++} which do not differ much in their exchange properties, the difference between the amounts of these cations reacting with the hydrogen clay is not so marked as it is between widely differing cations like Ca^{++}or Ba^{++} and Na^{+}, especially when the other factors, viz. concentration and *p*H, are high.

In the light of the work cited above it appears that when the salt concentration is high, the *p*H sufficiently high and the adsorption of cations strong, differences in the nature of the cation or *p*H should not much affect the estimated values of the base exchange capacity and those routine methods which satisfy more or less these conditions show fair agreement amongst themselves. But the differences as they exist are worthy of close scrutiny and it is also desirable to ascertain by varying the above factors whether there is a maximum limiting quantity of reacting acid associated with a given mass of a hydrogen clay or soil§. A comparative study has, therefore, been made of several routine methods for determining the b. e. c. of hydrogen clays and acid soils‖.

The hydrogen clays were prepared according to the procedure described in the earlier publications.

Lab.	*Description of soil*	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$
51	Highland acid soil on old alluvium from Jorhat, Assam ; unmanured, uncultivated, virgin soil under thatch grass	2·58	2·80
53	Highland acid soil on old alluvium from Latekujan, Assam ; unmanured, uncultivated virgin soil representing the submontane tract .	2·47	2·70

A comparison has been made of the following methods :

1. Parker's [1929] method—Ba^{++} adsorbed from a neutral, normal barium acetate solution was estimated.

* The expression 'acid soil' has been used to denote, as is usual, natural soils with an acid reaction and 'hydrogen soils' to denote desaturated soils obtained by exhaustive leaching with 0·02 N HCl assuming that the desaturation has been complete

† The results given in this paper were published in the Annual Report for 1939-40 on the working of the scheme of research into the properties of colloid soil constituents financed by the Imperial Council of Agricultural Research and directed by Prof. J. N. Mukherjee

** Assistant Soil Chemist under the above scheme during 1938-39

§ Some results on the attainment of a limiting value of the b. e. c. of soils have been already published in the *Proc. Indian Sci. Cong. Association* 1941. Results of further investigation will shortly be published

‖ A similar comparative study was carried out by Mitra and Mitra in this laboratory (*Indian J. agric. Sci.* **10**, 344)

2. Schollenberger's [1930] method—NH_4^+ adsorbed from a neutral normal solution of ammonium acetate was estimated.

3. Schofield's [1933] method—The amount of base taken up from a half neutralized (with lime) p-nitrophenol was estimated. The reaction takes place at *p*H 7·1.

4. Estimation of the amount of baryta taken up in presence of normal barium chloride to attain *p*H 7·0. This was determined as follows: To equal amounts (0·5 to 1·0 gm.) of the hydrogen clay to which equal volumes of N-$BaCl_2$ had been added in well-stoppered Jena bottles, increasing quantities of baryta were added. The mixtures were kept overnight with occasional shaking and their *p*H values measured by means of the glass electrode. From the titration curve thus obtained, the amount of base required to reach *p*H 7·0 was calculated.

5. Continuous potentiometric titration of the hydrogen clay (25 c.c. of a suspension of 10-20 gm./litre) with baryta in presence of N-$BaCl_2$ was carried out with the help of the glass electrode and the total acidity calculated from the amount of base taken up to reach *p*H 7·0. The time of interaction does not usually exceed 6 hours in these titrations.

6. The amounts of cation adsorbed on leaching with neutral normal solutions of NH_4Cl, $BaCl_2$ and $CaCl_2$ were also estimated. 500 c.c. of salt solution were used to leach the hydrogen clays (0·5 to 1·09). The quantities of Ba++ and Ca++ adsorbed were estimated in the leachate obtained with N-NH_4Cl. NH_4^+ adsorbed by the residue after it has been washed free of chloride was estimated by distilling with magnesia.

The results are given in Table I.

TABLE I

Hydrogen clay	N-$BaCl_2$—$Ba(OH)_2$ continuous titration (*i*)	N-$BaCl_2$-$Ba(OH)_2$ bottle titration (*ii*)	Parker (*iii*)	Schollenberger (*iv*)	Schofield (*v*)	Cation adsorbed		
						NH_4^+	Ba++	Ca++
Jorhat-F (from soil No. 51)	29·5	33·0	33·0	32·0	35·0	34·0	22·0	20·5
Latekujan-F (from soil No. 53)	51·5	56·5	54·0	55·0	55·0	56·0	42·0	40·0

Methods 1 and 2 give nearly the same values.* The close agreement between these two methods has been observed in the case of soils also in Part I of this paper. Method 3 gives a somewhat higher value with the hydrogen clay, Jorhat-F. Total neutralizable acidity calculated from the amonnt of base required to attain *p*H 7·0 (curves 1 and 2 for hydrogen clays JF and LF respectively, Fig. 1) is lower than those obtained by the other methods. If a longer time of interaction is allowed the titration with baryta in presence of N-$BaCl_2$ (curves 1′ and 2′ for hydrogen clays JF and LF, respectively, Fig. 1) gives values in general agreement with the above methods. Similar agreement was obtained in the case of hydrogen soils. Time of interaction is therefore one of the important factors in the reaction between the hydrogen clay and base.

In method 3 [Schofield, 1933] the cation (calcium) concentration is low (about N/50); in spite of this it gives values in close agreement with or even higher than the values obtained by the methods 1 and 2. This method has the distinction that it ensures a maximum buffering. The p-nitrophenol-hydrogen clay mixture is maintained throughout at *p*H 7·1. In the other methods, at least the initial stages of the interaction with base occur at a lower *p*H. The adsorption of Ca++ is quite strong in alkaline or neutral region [Mukherjee, Mitra and Mukherjee, 1937; Mitra, Mukherjee and Bagchi, 1940; Mitra, 1940; Mukherjee and Mitra, 1942]. The method also allows a long interval (16 to 18 hours) for the interaction. In the methods 1 and 2 it has been observed that on the addition of the hydrogen soil the neutral reaction of the salt solution is perceptibly displaced to the acid side of the *p*H scale. Similar lowering occurs with hydrogen clays and hence maximum buffering is not obtained.

The last three columns of Table I indicate that the order of adsorption of the cation from their neutral normal solutions is $NH_4^+ > Ba^{++} > Ca^{++}$. NH_4^+ adsorbed is almost equal to the maximum b. e. c. of the hydrogen clays given by the other methods. Similar observations have been made

* The features of the titration curves given in Fig. 1 are not discussed here; this will be done in another publication

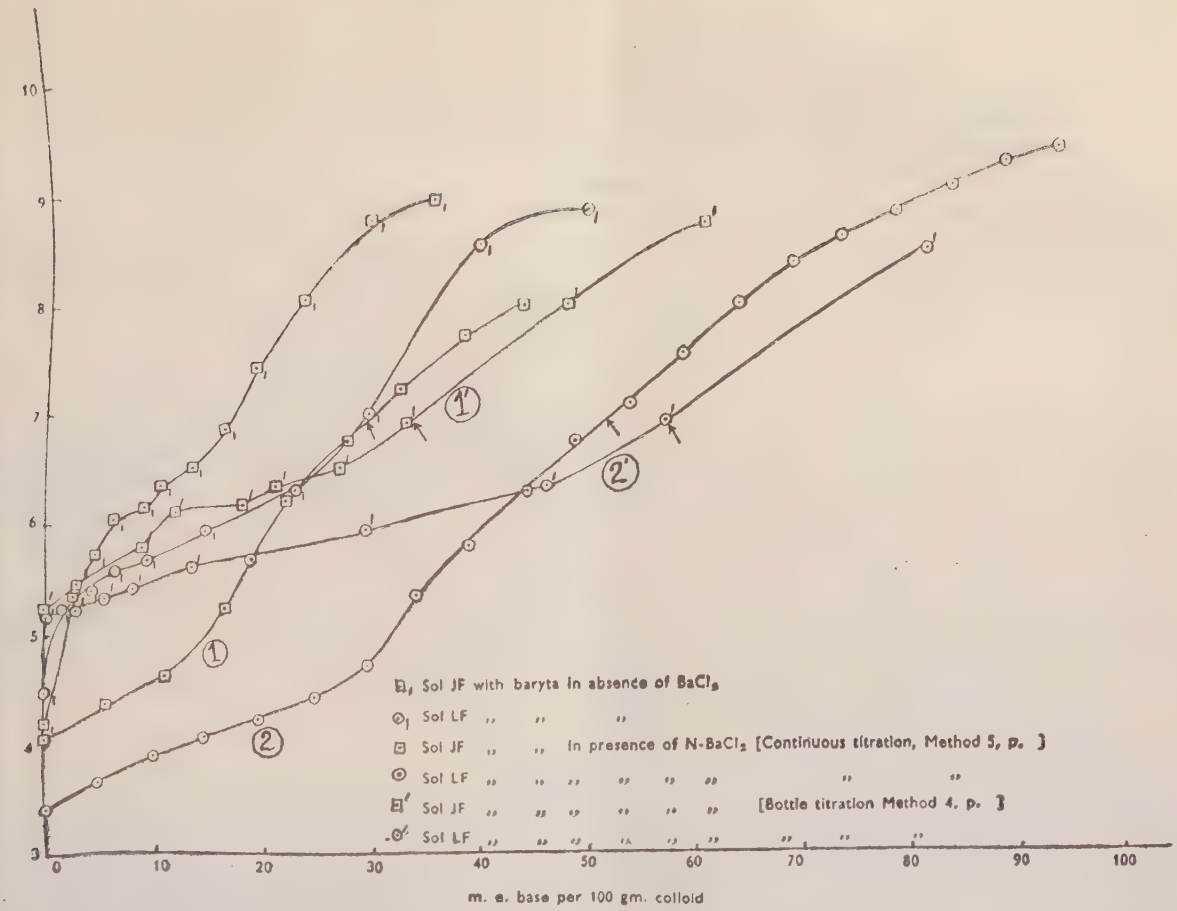
Sol JF with baryta in absence of BaCl₂
Sol LF
Sol JF in presence of N-BaCl₂ [Continuous titration, Method 5, p.
Sol LF
Sol JF [Bottle titration Method 4, p.
Sol LF
m. e. base per 100 gm. colloid

FIG. 1

with hydrogen soils (described below). The greater adsorption of NH_4^+ compared to either Ba^{++} or Ca^{++} ions is interesting.

Considering the electrical double layer [Mukherjee, 1922] associated with a hydrogen clay particle the reaction with a neutral salt can be visualized as follows: When a fairly high concentration of a salt is added to the hydrogen clay its cations will displace both free and bound hydrogen ions from the complex. The extent to which this exchange and desorption of hydrogen ions take place is indicated by the equilibrium pH of the mixture and will depend on the nature of the added cation. At all pH lower than the equilibrium pH the hydrogen ions will tend to be adsorbed at the expense of the added cation. At the high concentration (normal) of the salts usually employed for leaching the difference in the cation effects is not very large and it appears that the greater adsorption of NH_4 ion mainly results from the higher equilibrium pH of the mixture of hydrogen clay and NH_4Cl. In other words, under these conditions the pH effect becomes dominant. In the methods of Parker and Schollenberger the acetates act as buffer solutions so that leaching proceeds at a pH not far removed from 7·0.

The effects of the pH of the leaching solutions on cation adsorption and its relative order have been examined with respect to three 'hydrogen' soils prepared from the following soils by exhaustive leaching with 0·05N HCl. They were then washed free from HCl and air dried.

Lab. No.	*Description*
20	Kalyanpur Agricultural Farm soil, collected from a depth of 0-6 in. A typical loam
16A	Krishnagar Farm soil, collected from a depth of 6-12 in. A highland soil from Nadia
56	Oating Farm soil from Assam, collected from a depth of 6-12 in., from the fringe of the Mikir Hills, Assam. A highland acid soil, uncultivated and unmanured

The leaching and estimation of the cations adsorbed thereby were done by the procedure described earlier. The residual soil after treatment with N-NH_4Cl used for replacing the adsorbed cation was washed with alcohol until free from electrolytes. The adsorbed NH_4^+ was then

estimated by distillation with magnesia. The values are shown in the last two columns of Table II. The *p*H values of the leachates are generally less than those of the corresponding leaching solutions but the difference is almost negligible with NH_4Cl. When leaching has proceeded for a long time an almost constant *p*H is attained which is shown as the 'limiting' *p*H in Table II. One salt only was used for determining the 'limiting' *p*H for a particular soil. Neutral N-$BaCl_2$ for soil No. 20, neutral N-$CaCl_2$ for soil No. 16A and neutral N-NH_4Cl for soil No. 56 were used.

TABLE II

	Initial *p*H of salt solution	Limiting *p*H	*p*H of residual soil	*p*H of original soil	Amounts of cation adsorbed			NH_4+ adsorbed from NH_4Cl to displace adsorbed	
					Ba++	Ca++	NH_4+	Ba++	Ca++
Kalyanpur H-soil b. e. c. 11·9	2·2	2·3	4·2	..	3·7	3·2	5·8	10·4	10·2
	4·6	4·5	5·2	4·3	5·5	6·8	11·3	11·5	11·6
	7·0	6·0	5·5	..	7·1	8·1	11·7	11·6	11·6
	8·5	6·4	6·0	..	7·4	8·7	12·7	11·7	12·5
Krishnagar H-soil b. e. c. 9·2	2·0	2·1	4·2	..	2·9	2·4	4·8	9·0	9·0
	4·0	4·1	5·0	3·8	6·1	5·5	7·2	9·1	9·2
	7·0	5·9	5·8	..	6·3	6·4	9·0	..	..
	8·5	6·3	6·2	..	6·8	7·2	9·4	9·5	9·5
Oating H-soil b. e. c. 6·2	3·2	3·2	4·8	..	3·1	2·9	4·3	6·3	6·2
	7·0	6·8	7·8	3·5	3·2	3·4	6·3	6·4	..
	8·7	8·3	8·2	..	3·2	3·7	6·8	6·4	..

The limiting *p*H of NH_4Cl leachings is nearly the same as that of the stock solution used whereas those of the leachates of $BaCl_2$ and $CaCl_2$ are lower than those of the respective stock solutions.

The *p*H values of the treated soils on removal of the salt by washing after the leaching (the residual soil) are also recorded in Table II. They show that the residual soils have a more or less acidic reaction even when the leaching solutions were neutral $BaCl_2$ and $CaCl_2$. The acidic reaction definitely indicates the presence of unexchanged and osmotically active hydrogen ions in the complex.

The amounts of cation adsorbed have been plotted (Fig. 2) against the limiting *p*H*. Ba++ and Ca++ show reversal of the order of adsorption at *p*H between 4·0 and 6·0†. The Kalyanpore hydrogen soil shows it at 4·2, the Krishnagar hydrogen soil at 5·6. The adsorption of NH_4+ ion follows a different but an apparently regular course.

ESTIMATION OF THE LIME REQUIREMENT OF ACID, PARTLY DESATURATED AND HYDROGEN SOILS BY DIFFERENT METHODS

The methods of estimating the lime requirement of acid soils aim at measuring the content of exchangeable hydrogen. The large number of methods available for this purpose seldom give concordant values. The two types of cation effects the hydrogen ion activity of the solution and the time of interaction, as already mentioned and discussed in the preceding pages appear to afford a consistent explanation of the observed variations in these estimations.

The following methods have been used for comparison :

(3) Schofield's method [1933]

(4) Bottle titration

(7) Kappen's method [1916]

* In plotting these curves it has been assumed that the limiting *p*H values with $BaCl_2$ and $CaCl_2$ solutions are the same with all the soils, and those of NH_4Cl leachates the same as those of the salt solutions themselves. This can only be treated as a very rough approximation.

† Results on the interaction between hydrogen clays and baryta and lime obtained in this laboratory also show a similar reversal of adsorption of Ba++ and Ca++ ions.

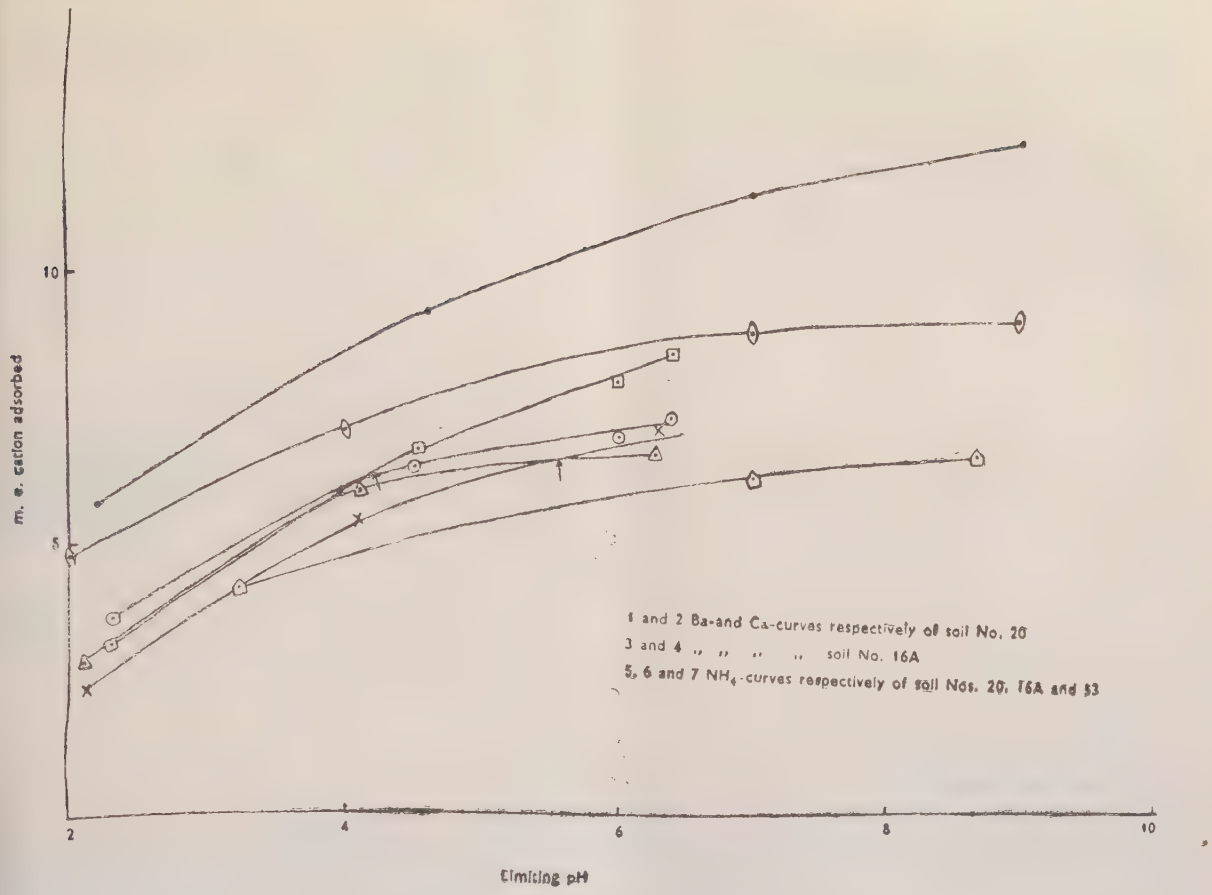

FIG. 2

(8) Daikuhara's method [1914]

(9) Parker's $Ba(OH)_2$—NH_4Cl method [1929]

(10) Hutchinson and McLennan's method [1914]

The two 'acid' soils (Nos. 51 and 53) and the following soils which were only partially desaturated have been used for the estimation of lime requirement.

Lab. No.	*Description*
16A	Krishnagar farm soil, Highland soil (0-6 in.).
34	Black cotton soil from Akola, C. P. (0-6 in.).

The two acid soils Nos. 51 and 53 were also completely desaturated and in addition the resulting hydrogen soils have been used making a total of six samples for this comparison.

Table III gives a comparative study of the values of b. e. c. of three naturally occurring soils used in this investigation and the H-soils§ prepared from them. The b. e. c. has been determined using either method 1 or 2 or both. The agreement between the b. e. c. of the naturally occurring soil and the corresponding H-soil shows that the base exchange property of the soil remains unaltered when converted to the H-soil. Methods of determining lime requirement of soils may therefore be applied to H-soils and the values so obtained may be compared with the b. e. c. of the soils themselves.

Table IV shows the results of the lime requirment of a number of acid and H-soils by the various routine methods. The b. e. c. (T) and the amount of exchangeable bases (S) were estimated by method 2. The quantity T—S in column 4 (Table IV) should be equal to the estimated lime requirement. This quantity is, however, obtained by computation as a difference between two quan

§ Soil No. 16A was also partly desaturated

TABLE III

Soil No.	Naturally occurring soil		Partly desaturated		H-soil	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
16A . . .	..	9·0	..	8·5	9·2	9·2
20 . . .	11·6 11·8	11·9	..	..	..	11·9
53 . . .	8·0 8·3	8·2 7·5	..	..	..	7·5

tities and is liable to a greater error than the quantities T and S and the error will be greater the smaller is the difference compared to the values of T and S. The S-value should not vary provided all the exchangeable bases have been displaced and estimated ; but as we have seen the T-value depends on the method employed for its determination.

TABLE IV

Soil No.	T*	S*	T-S	Lime requirement by methods†					
				7	8	4	9	3	10
16A (Partly desaturated) .	8·5	1·8	6·7	5·3	6·0	..	..	..	..
34 (Partly desaturated) .	54·7	20·5	34·2	14·2	14·0	..	..	..	..
51	5·9	1·9	4·0	4·0	1·8	5·8	..	5·6	4·5
51 (H-Soil)	5·9	..	5·9	6·0	5·8	6·8	7·2	7·5	5·9
53	7·5	3·3	4·2	3·9	4·1	5·4	..	5·9	4·5
53 (H-Soil)	7·5	..	7·5	6·5	6·9	7·6	8·4	8·0	7·7

* Estimated by Schollenberger's method

† Expressed in m. e. per 100 gm. of hydrogen soil

Methods 7 and 8§ give values in agreement with T—S in the case of the two acid soils where the amount of exchangeable hydrogen was small but they give smaller values for Nos. 16A and 34, especially the latter which contain larger amounts of exchangeable hydrogen. This observation can be understood from the balanced nature of the reaction between the acid soil and the salt solutions. In the case where the content of exchangeable hydrogen is large the *p*H of the medium appreciably diminishes and the back reaction is favoured but in the case where the amount of exchangeable hydrogen is small the *p*H of the solution does not change to any appreciable extent.

The single treatment used in the methods 7 and 8 seems to be sufficient for soils having comparatively small lime requirement. The agreement between methods 7 and 8, although they involve different cation effects, probably arises from the fact that the latter uses an empirical factor (3·5) by which the titre value of the first leachate is to be multiplied.

Methods 3, 4 and 9 give higher values than T—S given in column 4. In method 4 a longer time of interaction is allowed, in 9 the soil is kept in contact with a 0·1 N $Ba(OH)_2$ solution for about 18 hours, and in 3 the soil is kept in contact with a solution of *p*H 7·1 for about 16 hours. The three methods (3, 4 and 9) ensure that *p*H, the concentration of a strongly adsorbed cation and the time of interaction are all fairly high. The differences shown between them indicate the extent to which one or more of the factors are dominant. They give a higher estimation of the exchangeable

§ A much smaller value is obtained for soil No. 51

hydrogen than obtained by methods 1 and 2. In method 10 the cation (Ca^{++}) concentration is about N/50, the pH of the bicarbonate solution is 6·6 which rises to 7·1 on treatment with the soil but the shorter time of interaction (3 hours) probably explains the low values obtained by this method compared to the above three. The latter values are however in good agreement with the T—S. Probably the methods 3, 4 and 9 estimate less reactive hydrogen ions in addition to the more reactive ones estimated by the method 10 or included in the quantity T—S.

Summary and conclusion

1. In view of the lack of agreement amongst the various methods of determining the base exchange capacity (b. e. c.) of soil, a comparative study has been made of several routine methods using hydrogen clays and hydrogen and acid soils. It would appear from the results recorded in this paper that the differences in the cation and pH effects and the time of interaction account for this lack of agreement.

2. It has been found that Parker's and Schollenberger's methods give nearly the same value. At the high pH, high concentration of the salts and at the neutral reaction the cation effect practically vanishes. Schofield's method gives a somewhat higher value. This may be accounted for (1) by the neutral reaction (pH 7·1), (2) by the greater adsorption of Ca^{++} in this pH region and (3) longer time of interaction (16 to 18 hours). The continuous titration (which takes about 6 hours) of hydrogen clays with baryta in presence of normal barium chloride gives a lower values but if the titration is carried out in bottles allowing a longer time of reaction (about 16 hours), the observed b. e. c. is in good agreement with either Parker's or Schollenberger's method.

3. The amounts of Ba, Ca and NH_4 adsorbed by the hydrogen clay from neutral normal solution of their chlorides are in the order $NH_4^+ > Ba^{++} > Ca^{++}$.

4. It has been observed that the pH of the successive leachates with $BaCl_2$, $CaCl_2$ and NH_4Cl gradually increases reaching a constant value. This 'limiting' pH in the case of NH_4Cl is higher than those in the case of $BaCl_2$ and $CaCl_2$. pH effect is the dominant factor in determining the greater adsorption of NH_4^+.

5. The adsorption of Ba^{++}, Ca^{++} and NH_4^+ from their chloride solutions increases with the pH of the leaching solutions. The adsorption of Ca^{++} and Ba^{++} shows reversal between pH 4 and 6.

6. The base exchange property of a soil remains in tact when it is converted into the H-soil. Methods of determining lime requirement may therefore be applied to soils after converting them to H-soils and the values of lime requirement may be compared with their b.e.c. Lime requirements of some acid, partly desaturated and hydrogen soils were determined by six different methods. The values obtained by the various methods were compared with T-S obtained by Schollenberger's method. The methods of Kappen and Daikuhara are in good agreement with that of Schollenberger when the amount of exchangeable hydrogen is small but they give smaller values for soils which contain larger amount of exchangeable hydrogen. Titration with baryta in presence of N-$BaCl_2$ using longer time of interaction (bottle titration) gives higher values than by continuous titration. Parker's $Ba(OH)_2$-NH_4Cl and Schofield's methods give values higher than T-S. The higher values are to be ascribed to the pH and time effects only. The lower value obtained by Hutchinson and McLennan's method in which the pH is also 7·1 is due to the shorter period of interaction (3 hours).

References

Daikuhara, (1914). Acid mineral soils. *Bull. Imp. Central Agric. Exp. Sta., Tokyo*, **2**, 1

Hutchinson, H. B. and McLennan, K. (1914). The determination of the lime requirements of the soil. *Chem. News* **110**, 61

Kappen, H. (1916). Causes of acidity of soils which are acid through exchange of ions. *Landw. Versuchsstat.* **88**, 13

Mitra, R. P. (1931). On the nature of reactions responsible for soil acidity, V. Titration curves of clay acids. *Indian J. agric. Sci.* **6**, 555

——— (1940). On the nature of reactions responsible for soil acidity, VII. The electrochemical properties of colloidal solutions of hydrogen clays. *Indian J. agric. Sci.* **10**, 317

——— ——— Mukherjee, S. K. and Bagchi, S. N. (1940). On the nature of reactions responsible for soil acidity, VI. The variability of the total neutralizable acid of colloidal solutions of hydrogen clays. *Indian J. agric. Sci.* **10**, 303

Mukherjee, J. N. (1922). The adsorption of ions. *Phil. Mag.* **44**, 321

Mukherjee, J. N., Mitra, R. P. and Mukherjee, S. (1937). The characteristic properties of colloidal solutions of acidic substances which distinguish them from acids in true solution. *Trans. Natl. Inst. Sci., India*, **1**, 227

Mukherjee, J. N. and Mitra, R. P. (1942). On the nature of reactions responsible for soil acidity, IX. The acid character of hydrogen clays. *Indian J. agric. Sci.* **12**, 433

Mukherjee, J. N., Mitra, R. P., Chatterjee, B. and Mukherjee, S. K. (1942). On the nature of reactions responsible for soil acidity, VIII. The acid character of hydrogen clay in relation to some problems of soil science. *Indian J. agric. Sci.* **12**, 86

Parker, F. W. (1929). Determination of exchangeable hydrogen in soils. *J. Amer. Soc. Agron.* **21**, 1030

Schofield, R. K. (1933). Rapid methods of examining soils, II. Use of p-nitrophenol for assessing lime status. *J. agric. Sci.* **23**, 252

Schollenberger, C. J. and Dreibelbis, F. R. (1930). Analytical methods in base exchange investigations on soils, *Soil Sci.* **30**, 161

STUDIES IN SOIL DISPERSION

II. EFFECT OF *p*H VALUE AND THE NATURE OF EXCHANGEABLE BASE ON DISPERSION OF SOIL

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It has been shown that dispersion is complete and at its maximum when the *p*H value of a H-soil is made equal to 10·8 by the addition of NaOH or LiOH [Puri and Manohar Lal, 1938]. Some interesting considerations arise out of this, namely, whether the soil, at different *p*H values, which is not at its maximum dispersion, represents a stable structure or it is merely a question of time. It is quite likely that the rate of dispersion of soil at different *p*H values might be different, in which case it would be more helpful to measure the rate of dispersion. The development of the Chaino-hydrometer [Puri and Puri, 1939] for the mechanical analysis of soils has made this study possible because the same suspension could be examined at different intervals of time which would not have been possible with the pipette method.

Rate of dispersion of sodium-soil

A black cotton soil (lab. No. P. C. 13) was freed from exchangeable bases by treatment with *0·05 N*HCl. Increasing amounts of NaOH were then added to the treated soil and the volume made to give a 2 per cent suspension. Particles of 0·005 mm. were determined at various intervals of time. The results are given in Table I. The readings were continued for 50 days after which the suspensions were heated for 10 hours at 60-70°C. It will be seen from Table I that differences due to *p*H values are maintained throughout. There is, however, a slight tendency for the dispersion to increase during 5-7 days up to *p*H 10 or so. Dispersions at higher *p*H values seem to have reached a maximum value in four hours. It is clear that soils at different *p*H values represent structures which, if not permanent, are at least stable for a reasonable length of time, i.e. 50 days.

The effect of *p*H value on dispersion is also brought out quite clearly from the above data (Table I) which shows that the differences in dispersion at different *p*H values are maintained even on heating for 10 hours after keeping for 50 days.

In order to see if this state of aggregation is only confined to the clay fraction or to the whole of the soil including coarser fractions as well, complete mechanical analyses up to 0·06 mm. particles were determined after leaving P.C. 13 soil with increasing amounts of alkali in 2 per cent suspensions for three weeks. The results are given in Table II and show that the relation between *p*H and dispersion is the same whatever size of particle is taken into consideration. In other words, the alkali affects all the fractions equally. It would seem as if clay is uniformly distributed throughout the entire soil and as dispersion increases, each fraction contributes a share of clay proportional to size or surface.

Table I

Rate of dispersion of P. C. 13 H-soil at different p*H levels*

*p*H (taken after 48 hours)	Per cent (<0·005 mm.) particles after keeping for various intervals of time													
	4 Hours	8 Hours	12 Hours	24 Hours	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days	14 Days	30 Days	50 Days	50 days after heating for 10 hours
5·90	6·2	7·6	6·5	6·2	8·4	8·3	9·8	9·4	9·6	9·5	9·5	11·6	12·7	12·7
6·62	9·6	9·7	10·0	10·3	11·7	12·5	13·4	13·2	13·7	14·3	11·6	17·4	19·2	21·2
7·71	12·9	13·2	13·0	14·3	14·8	15·9	19·1	18·6	18·9	19·6	23·8	25·2	28·0	29·4
7·92	15·3	15·6	15·9	18·5	20·4	21·1	21·6	22·3	23·0	23·5	25·4	27·6	29·1	31·0
8·60	14·9	15·4	16·9	21·7	22·9	23·9	24·1	24·9	26·7	27·3	28·7	32·7	34·4	34·9
9·24	16·6	18·7	21·0	23·1	26·0	27·9	28·2	28·8	30·9	31·0	31·3	33·4	35·8	36·2
9·60	18·8	21·6	23·7	26·7	29·4	31·5	31·9	32·6	32·6	34·1	35·3	36·3	38·0	38·4
9·92	24·6	30·8	34·1	38·7	41·4	42·6	43·0	44·1	45·6	45·8	46·1	47·2	47·2	47·5
10·52	60·5	60·9	60·7	61·3	61·1	62·9	62·7	61·0	60·8	60·3	59·7	60·5	59·7	60·6
10·95	64·2	64·6	65·2	62·3	63·0	62·9	61·9	62·2	61·6	61·2	60·9	61·2	61·6	62·3

TABLE II

Complete mechanical analysis of P. C. 13 A.T. at different pH values (after 3 weeks keeping)

*p*H	Quantity of N/10 NaOH added to 50 gm. of soil	0·06 mm.	0·04 mm.	0·02 mm.	0·01 mm.	0·008 mm.	0·005 mm.	0·002 mm.
5·55	6	58·0	52·0	37·5	31·6	30·4	27·7	23·5
6·16	15	66·3	59·2	51·4	42·6	39·4	36·3	31·3
6·60	20	68·0	64·4	54·3	45·8	43·6	38·4	35·0
7·15	24	71·8	68·0	55·0	47·2	46·9	42·2	37·5
7·45	28	72·9	69·1	59·7	51·2	48·7	44·8	39·6
8·25	34	79·3	73·8	66·2	54·1	51·7	47·3	43·2
9·40	40	83·0	81·3	68·9	57·5	56·5	51·5	44·3
9·95	50	83·8	82·7	74·0	64·2	63·4	58·2	51·9
10·80	70	84·4	82·9	77·7	65·9	64·4	59·2	54·3
11·10	100	85·4	83·5	77·2	67·4	65·4	61·4	57·2

EFFECT OF THE NATURE OF EXCHANGEABLE IONS ON DISPERSION

Increasing amounts of various hydroxides, were added to a H-soil (undispersed) and dispersion measured at every step by determining particles of 0·005 mm. diameter with the Chaino-hydrometer. The total quantity of alkali added in this case was a little more than generally required for the maximum dispersion, the reason for which will be explained presently. The results are given in Table III. The greater efficiency of Na and Li ions is apparent. This soil requires approximately 60-70 c.c. of N. alkali for 50 gm. to bring it to *p*H 10·8. When the addition of alkali is pushed still further a slight increase in dispersion is noticed which continues until flocculation takes place. This gradual rise is most probably due to the partial breakdown of the alumino silicates. It might be pointed out that the quantity of alkali added was subtracted from the weight of the suspended matter in every case.

TABLE III

Effect of the nature of exchangeable ions on dispersion

M. E. of various alkalies added to 50 gm. of soil	Lithium		Sodium		Potassium		Ammonium		Calcium		Magnesium	
	*p*H	Percentage 0·005 mm.	*p*H	Percentage <0·005 mm.	*p*H	Percentage <0·005 mm.	*p*H	Percentage 0·005 mm.	*p*H	Percentage <0·005 mm.	*p*H	Percentage <0·005 mm.
10	6·19	16·1	6·15	9·2	6·05	4·2	6·0	5·3	5·2	5·0	4·88	5·1
20	8·04	32·2	8·02	18·3	8·00	5·6	7·8	7·3	6·0	5·8	6·80	6·2
30	9·30	42·0	9·28	28·2	9·35	5·8	9·2	9·5	7·0	6·6	8·20	7·28
40	10·06	52·7	10·02	40·2	10·20	7·5	9·38	11·8	8·0	6·7	8·70	9·14
50	10·36	56·8	10·30	49·4	10·46	11·8	9·42	14·6	8·6	7·6	8·86	9·69
60	10·62	59·5	10·58	57·5	10·80	13·5	9·46	15·5	8·8	7·9	9·12	10·30
70	10·76	59·6	10·74	59·1	10·90	17·8	9·44	18·0	9·0	7·6	9·20	10·68
80	11·12	60·0	11·12	60·8	11·18	25·7	9·42	20·0	8·98	7·2	9·54	10·80
90	11·18	61·3	11·18	63·1	11·24	27·9	9·54	21·8	9·10	6·0*	9·60	6·55*
100	11·18	61·4	11·18	63·2	11·26	31·0	9·52	23·1	9·16	4·0	9·72	1·96
110	11·25	63·9	11·28	63·9	11·34	30·6	9·58	22·8	9·18	3·4	9·70	1·76
120	11·28	61·8	11·29	67·8	11·36	34·2	9·64	24·5	9·20	3·0	9·74	1·00
130	11·30	61·5	11·30	68·3	11·44	32·8	9·70	26·25	...	...	9·70	...
140	11·32	62·9	11·37	71·6	11·40	23·1*	9·66	26·85	...	...	...	...
150	11·60	64·9	11·55	Flocculates	11·66	15·4	9·80	26·80	...	...	...	...

*Flocculation begins at this point

Complete mechanical analysis of P. C. 13 soil dispersed with different bases was also done. Sixty milli equivalents of alkali were added to 50 gm. of the H-soil in every case and suspensions left for three weeks after which they were mechanically analysed. The results are given in Table IV. It is seen that the effect of different ions on dispersion is similar to the effect of various *p*H values (Table II).

In the experiments described above, the H-soil used was in the dry and therefore undispersed state. It is known that if a dispersed H-soil is taken and the various ions introduced into the complex by the addition of equivalent amounts of various hydroxides, the dispersion, as regards conventional clay, is unaffected by the nature of the exchangeable ion [Puri, 1930]. However, it is quite likely that such differences might appear

TABLE IV

Complete mechanical analysis of P. C. 13 A.T. dispersed with different bases (after three weeks keeping)

(60 m.e. of alkalies were added to 50 gm. of soil)

	0·06 mm. per cent	0·04 mm. per cent	0·02 mm. per cent	0·01 mm. per cent	0·008 mm. per cent	0·005 mm. per cent	0·002 mm. per cent
Li	82·9	79·1	76·9	66·4	64·8	60·1	55·3
Na	82·4	79·7	75·4	66·6	64·1	60·7	55·0
K	52·2	43·3	27·8	17·4	17·1	12·4	6·8
NH_4	57·42	47·10	36·7	23·8	21·2	17·0	14·50
Ca	48·45	35·10	25·6	10·2	9·0	8·0	4·80
Mg	55·40	41·90	28·0	14·6	14·0	10·4	6·00

in the case of ultra-clay. Two soils, P. C. 13 and 123 were used for this study. These soils represented two distinct types as regards their ultra-mechanical analysis. As lithium ions give the highest dispersion, the soils were first completely dispersed with LiOH. They were then treated with *0·05 N*.HCl to remove all the bases and then without drying they were shaken with equivalent amounts of various hydroxides and the size distribution of particles determined as usual by the pipette method. The results are given in Table V. It is seen that there is practically no influence of the nature of the ion down to particles of 0·00043 mm. diameter. The difference becomes marked only in the case of 0·000177mm. particle and even then only as regards monovalent and divalent ions with the exception of H which behaves more like the divalent ions. Another observation made in this connection was that single base soils containing divalent ions showed a tendency to become flocculated in the course of time. This is indicated in Table I along with the particular fraction where it was noticed. These results are interesting in showing that the only stable suspensions are the saloids of alkali metals, others tending to flocculate in the course of time.

TABLE V

Ultra-mechanical analysis of soils with different ions

Nature of ions	Percentage of particles below various sizes				
	0·002 mm.	0·001 mm.	0·00043 mm.	0·00029 mm.	0·000177 mm.
P.C. 13 Soil—					
Ca	56·46	52·83	40·66	27·66(F)	..
Ba	55·72	38·42(F)	..	..	..
Sr	53·70	51·53	43·33	37·93	28·07(F)
Mg	52·70	50·00	40·11	37·84	24·73(F)
H	53·40	49·83	43·60	38·20	28·40(F)
NH_4	54·05	50·67	44·23	42·73	42·57
Na	54·16	53·60	46·53	46·30	44·86
K	53·95	53·30	42·86	43·73	40·63
Li	54·05	53·83	46·33	43·57	42·46
P.C. 123 Soil—					
Ca	75·60	74·58	57·20	38·35(F)	14·70(F)
Ba	76·35	74·70	58·70	49·20	9·10(F)
Sr	74·10	74·95	29·00(F)	..	..
Mg	75·65	73·05	61·30	49·90	26·15(F)
NH_4	77·40	73·90	56·55	49·50	38·00
Na	75·15	73·85	57·65	49·35	40·20
K	78·05	74·20	58·25	50·60	39·35
Li	77·65	75·45	59·55	51·80	42·65

Hydration of soil colloids—a factor in clay determination

The high dispersion of soil colloids in the presence of Li and Na ions has been generally ascribed to the hydration of these ions. This is quite conceivable as the association of these ions with water molecules could easily overcome the cohesive forces binding the particles together. The hydration may have the effect of decreasing the density thus making them lighter or increasing the friction between the surface of particles and water. This will have the effect of lowering the rate of settling, so that if no account is taken of these factors and settling velocities calculated according to Stokes Law, the pipetting in the mechanical analysis will be made 'too soon' and a portion of the particles of higher diameters will be included, resulting in a higher value for clay. It is an important consideration, because if it is so it will be necessary to look upon some of these estimations in the presence of highly hydrated ions as 'apparent' clay. It has already been seen that a completely dispersed clay is unaffected by the nature of the exchangeable ion provided it is not allowed to dry (Table V). All the monovalent ions, which are admittedly hydrated to varying extents, show the same percentage of clay down to 0·000177 mm. particles. Hydration, therefore, cannot be a factor influencing the settling velocities of these particles. There is another method of throwing light on this point. Clay can be determined at higher temperature, and if hydration is playing any part, there should be a decrease in the clay content due to dehydration. P. C. 13 and 123 soils were chosen for this experiment, as they had the highest base exchange capacity, and, therefore, likely to show the maximum effect of hydration if any. The soils were first brought to a state of maximum dispersion and then various ions introduced after acid treatment as described in the above paragraph. Clay (<0·002 mm.) was determined at three different temperatures, the highest being 64°C. in the case of P. C. 13 and 58°C. in the case of P. C. 123. The results given in Table VI leave no doubt that, whatever effect the hydration may have in breaking up the aggregates, it has no influence on the settling velocities. It is remarkable that Stokes' Law is applicable over such a wide range of temperature in the case of the conventional clay fraction.

Effect of temperature on dispersion

Effect of temperature on dispersion at different *p*H values was studied by keeping a H-soil with increasing amounts of NaOH in thermos flasks for 24 hours and also by shaking mechanically for the same period. There was a change of temperature of about 5°C. during the period the suspensions were kept or shaken. The results are given in Table VII and show that an increase in temperature leads to a higher dispersion at all *p*H values, the maximum difference being shown at the highest *p*H value when the suspension was not shaken. The maximum value, however, showed little difference when the suspensions were shaken.

The same effect is shown in a more striking manner in Table VIII in which the rate of dispersion of the soil at two temperatures is recorded. It is seen that at 35°C. the soil is completely dispersed in about 4 hours whereas at 11°-12°C. it takes no less than six days to reach the same state of dispersion.

Table VI

Effect of temperature on the clay content of soils with different ions

Nature of ions	Percentage of clay (0·002 mm.)		
P. C. 123 Soil—	25°C.	1°C.	58°C.
Barium	78·80	74·90	73·40
Calcium	78·40	76·50	75·15
Strontium	76·20	76·85	73·80
Magnesium	75·40	77·80	74·90
Hydrogen	73·00	75·05	72·80
Ammonium	77·05	77·85	71·20
Potassium	76·40	74·60	73·85
Sodium	78·80	75·30	74·45
Lithium	79·55	77·10	74·90
P. C. 13 Soil—	24°C.	1°C.	64°C.
Barium	55·70	55·00	Flocculates
Calcium	53·90	52·00	49·57
Strontium	54·90	53·70	54·13
Magnesium	54·57	53·20	52·15
Hydrogen	53·87	51·23	50·83
Ammonium	52·83	50·87	53·33
Potassium	53·57	52·00	53·53
Sodium	56·20	53·80	55·57
Lithium	56·37	52·73	54·23

Effect of dilution on dispersion

Effect of soil/water ratio on the physico-chemical properties of the suspension such as the *p*H value and conductivity are well known. In order to complete the analogy between clay suspensions and solutions of weak electrolytes the effect of dilution on soil dispersion must be known. 12 gm. portions of a highly clayey H-soil were dispersed at different *p*H values by keeping in contact with 200, 400, 600, 800 and 1,000 c.c. of water for 10 days, no mechanical shaking being given. After that the volume was made 1,200

TABLE VII

Effect of temperature on dispersion at different pH values

Milli-equivalents of NaOH added to 12 gm. of soil	*p*H (Mean of 4 readings)	A. No shaking was given. The samples were kept at their respective temp. for 24 hours. Percentage $<0\cdot005$ mm. particles at various temperatures				*p*H (Mean of 4 readings)	B. Samples were shaken for 24 hours at their respective temperatures. Percentage $<0\cdot005$ mm. particles at various temperatures			
		8-12°C.	17-22° C.	28-33° C.	38-44°C.		9-14°C.	19-25°C.	30-35°C	39-49°C.
1·5	6·3	9·4	13·4	15·4	17·0	6·2	28·2	29·8	32·8	32·2
3·5	7·05	19·2	21·6	24·0	28·4	7·05	31·6	33·6	36·0	36·6
5·0	9·05	25·6	27·6	29·4	32·4	8·00	34·6	37·0	39·6	39·4
6·5	9·9	27·6	29·8	31·6	36·0	9·2	42·6	46·0	47·6	49·6
9·0	10·55	29·2	33·6	37·0	39·6	10·15	50·2	54·4	55·6	55·8
11·0	10·86	29·6	35·8	40·8	42·8	10·65	55·4	56·4	59·6	60·8
16·5	11·20	37·0	40·8	41·6	50·0	11·15	59·0	58·6	58·4	61·4
25·0	11·56	41·5	45·9	49·6	62·6	11·52	57·9	58·9	58·1	62·1

TABLE VIII

Effect of temperature on rate of dispersion

Time	Percentage 0·005 mm. particles at *p*H 11·0	
	35°C.	11-12°C.
4 hours	64·2	..
8 hours	64·6	26·6
12 hours	65·2	28·8
24 hours	62·3	32·1
48 hours	63·0	39·1
3 days	62·9	..
4 days	61·9	49·3
5 days	62·2	54·8
6 days	61·6	58·2
7 days	61·2	60·0
14 days	62·2	61·7

c.c. in every case to give 1 per cent suspension. The results are recorded in Table IX. It will be seen that the effect of dilution is not apparent up to *p*H 9·82 but at higher *p*H values the higher dilutions give greater dispersion. The soil used for this experiment was extremely sensitive to *p*H changes as regards dispersion and therefore particularly suited for the purpose. These results again point to the analogy between solutions of weak electrolytes and clay suspensions. The increase in dispersion on dilution fits in well with the increase in activity of electrolytes on dilution.

SUMMARY

The effect of *p*H value, the nature of the exchangeable base, temperature and dilution on soil dispersion was studied. The *p*H value is by far the most important factor. The state of aggregation of the soil reached at different *p*H values represents a comparatively stable structure which undergoes very little change even on keeping for 50 days or heating to a temperature of 60°-70°C. Sodium and lithium are the only bases which give maximum dispersion. The effect of rise in temperature is similar to increase in dilution both leading to enhanced dispersion.

TABLE IX

Effect of dilution on dispersion at different pH values

(Soil No.123—A. T.—1 per cent suspension was prepared)

(After the addition of alkali samples were kept for 10 days. No shaking was given)

Quantity of N. NaOH added to 12 gm. of soil	*p*H (taken after 10 days)	Volume c.c.	0·06 mm. per cent	0·02 mm. per cent	0·01 mm. per cent	0·005 mm. per cent	0·002 mm. per cent
		200	75·85	51·20	38·8	35·2	33·0
		400	77·0	54·8	41·6	36·4	35·6
3 c.c. . .	9·20	600	74·4	51·6	39·2	34·8	35·3
		800	76·6	49·0	38·8	34·8	33·0
		1000	76·6	48·8	38·9	34·6	33·2
		200	83·6	58·4	48·8	45·6	45·5
		400	82·4	60·8	52·0	47·6	45·3
5 c.c. . .	9·82	600	83·2	59·8	51·0	47·1	46·4
		800	82·9	56·8	48·4	45·0	44·8
		1000	..	..	..	..	..
		200	84·6	66·2	62·2	56·6	56·3
		400	85·1	65·6	64·3	58·2	57·9
8 c.c. . .	10·36	600	87·2	74·6	70·6	67·4	65·9
		800	88·4	75·4	71·9	67·9	67·7
		1000	89·0	76·6	72·4	68·4	68·2
		200	87·90	74·8	68·8	62·5	61·7
		400	89·8	79·2	74·4	72·4	71·0
16 c.c. . .	11·40	600	92·05	83·8	82·0	80·0	78·8
		800	92·9	83·0	81·7	79·4	78·8
		1000	93·6	84·8	83·0	81·9	80·4

The hydration of ions has apparently no effect on the settling velocities of soil particles as calculated from the Stokes' Law.

REFERENCES

Puri, A. N. (1930). Studies in soil colloids, II. Factors influencing the dispersion of soil colloids in water. *Imp. Instt. Agric. Res. Pusa, Chem. Ser. Vol. XI*, 39-51

Puri, A. N. and Manohar Lal (1938). Dispersion and stability of soil colloids in water, I. Auto-disintegration. *Pb. Irrig. Res. Inst. Res. Pub. Vol. IV*, No. 10

Puri, A. N. and Puri, B. R. (1939). Physical characteristics of soils, IV. Density gradients in sedimenting columns and a chaino-hydrometer for mechanical analysis of soils. *Soil Sci.* **48**, 149

STUDIES IN SOIL DISPERSION

III. EFFECT OF VARIOUS PRELIMINARY TREATMENTS ON ULTRA-MECHANICAL ANALYSIS OF SOILS

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A good deal of work has been done on the effect of preliminary treatment of the soil on its mechanical analysis. Very little, however, is known about the effect of such treatment on its ultra-mechanical analysis. It is not unlikely that some of the more drastic treatments might result in a partial destruction of some of the finer fractions while not affecting the percentage of conventional clay. Attention was therefore directed mainly to those treatments which are likely to prove too drastic.

Destruction of humus

Humus is known to play an important part in the dispersion of soils. It acts as a cementing material, thereby, preventing the dispersion of soil aggregates. Robinson [1932] found that certain Welsh soils rich in organic matter did not disperse fully even after the removal of exchangeable calcium and calcium carbonates. He suggested preliminary oxidation of organic matter with boiling H_2O_2 solution. This method was later adopted as the International method of preliminary treatment of soils for mechanical analysis. Hydrogen peroxide, however, was found to be not quite a suitable reagent on account of its being expensive as well as troublesome especially in hot climates. Crowther and Troell [1932] suggested the use of cold solution of sodium hypobromite, while Chakraborty [1935] advocated the use of alkaline potassium permanganate. Puri and Sarup [1937, 2] introduced a few modifications in the details of Chakraborty's method and also showed [1937, 1] that the efficiency of alkaline $KMnO_4$ for oxidising organic matter was greater than that of H_2O_2.

The use of alkaline permanganate, however, may be objected to on the ground that it is too drastic and might easily result in the destruction of a part of the inorganic soil colloids. This adverse effect would naturally be confined to particles of ultra-clay. It was, therefore, of interest to study the effect of this treatment on the ultra-mechanical analysis. Eight soils were used for this study. These soils were not rich in humus as the object was to find out what effect the treatment had on the inorganic colloids. The soils after being freed from exchangeable bases were treated with alkaline $KMnO_4$ in accordance with the directions given by Puri and Sarup [1937, 2] and were dispersed by shaking them for 24 hours in presence of sufficient NaOH to raise the *p*H value to 10·8 [Puri and Manohar Lal, 1938]. Ultra-mechanical analyses of these soils before and after the treatment were determined by the Micro Pipette technique [Puri and Puri, 1941]. The results given in Table I show that oxidation with alkaline $KMnO_4$ has not produced any striking difference in the ultra-clay.

From the results it will also be seen that the preliminary destruction of organic matter is not necessary when the acid-treated soils are dispersed by the addition of sufficient amount of NaOH. In order to find out if it is also true in the case of soils containing excess of humus, 10 soils, rich in organic matter, were freed from exchangeable bases and dispersed by the addition of NaOH both before and after the preliminary treatment with alkaline $KMnO_4$. The *p*H value of each suspension was brought to 10·8. The results recorded in Table II reveal the following facts :

(1) When soils are not freed from humus, consistently higher values are obtained for all the fractions.

(2) The difference in the two sets of values obtained for a soil is of the order of the percentage of humus present in that soil. It is interesting to note in this connection that humus itself in alkaline solutions has got no ultra-mechanical analysis and all particles appear more or less to be of uniform diameter up to the limit to which the ultra-mechanical analysis can be pushed. This will be clear from the results of an experiment (Table III) in which humic acid was peptised with NaOH and then subjected to ultra-mechanical analysis.

(3) Humus on account of its solubility in NaOH no longer acts as a cementing material if dispersion is brought about by the HCl—NaOH method.

(4) In order to obtain the correct and not unduly high values of mechanical analysis of the mineral colloids preliminary destruction of organic matter in case of soils rich in humus is essential.

TABLE I

Effect of employing alkaline $KMnO_4$

Soil No.	Per cent humus	Treated or untreated with $KMnO_4$	Summation percentages of particles of various diameters in mm.					
			0·001	0·00063	0·00025	0·0001	0·000063	0·00004
116	1·2	Untreated . .	24·8	22·4	18·1	12·7	7·6	6·0
		Treated . .	23·3	20·4	16·9	11·0	6·6	5·6
183	0·5	Untreated . .	8·4	7·0	6·1	4·1	3·5	0·8
		Treated . .	10·2	9·2	8·3	3·5	3·1	1·2
242	0·8	Untreated . .	15·8	13·5	11·2	7·0	5·6	4·5
		Treated . .	15·2	13·2	11·9	5·4	4·0	3·2
243	0·5	Untreated . .	11·1	10·0	8·0	3·6	2·6	2·0
		Treated . .	9·5	8·3	6·3	4·5	2·0	2·0
244	0·2	Untreated . .	37·0	29·0	20·1	12·4	9·0	5·2
		Treated . .	36·5	30·8	21·5	12·6	9·6	7·6
245	0·5	Untreated . .	30·1	28·6	20·5	12·6	10·2	9·8
		Treated . .	34·8	29·0	20·9	13·5	9·6	7·8
250	0·45	Untreated . .	8·2	8·0	6·0	4·5	4·0	3·6
		Treated . .	10·4	9·0	7·2	3·8	3·1	2·8

(5) The alkaline permanganate method of destroying organic matter does not affect the mineral colloids and therefore cannot be considered as too drastic a preliminary treatment of the soil for mechanical analysis.

TABLE II

Comparison of ultra-mechanical analysis of soils with and without the destruction of humus

Soil No.	Per cent humus	Humus freed or not	Summation percentages of particles of various diameters in mm.						
			0·002	0·001	0·00063	0·00025	0·001	0·000063	0·00004
M-8	4·5	Humus not freed .	32·8	30·0	26·2	22·6	15·9	12·5	10·8
		Humus freed . .	30·0	27·1	23·8	20·2	12·1	9·0	8·1
M-12	4·1	Humus not freed .	25·6	24·0	20·9	15·1	13·3	10·0	9·5
		Humus freed . .	22·2	19·2	17·2	11·7	9·9	7·2	6·0
M-19	6·3	Humus not freed .	36·6	33·2	27·1	20·0	14·2	12·8	11·2
		Humus freed . .	30·8	27·5	21·8	15·2	11·5	8·0	7·0
M-40	5·25	Humus not freed .	63·0	58·2	45·0	37·3	30·2	22·5	21·5
		Humus freed . .	57·9	52·4	39·2	32·0	25·2	17·2	16·6
M-41	3·77	Humus not freed	66·4	63·4	56·2	44·0	24·5	13·5	9·8
		Humus freed . .	62·1	59·0	52·4	41·8	21·6	10·9	6·8
P-C.2	5·78	Humus not freed .	24·4	20·6	16·1	12·5	11·9	11·2	9·2
		Humus freed . .	18·6	15·2	12·5	9·4	8·8	7·1	5·0
P.C. 3	4·66	Humus not freed .	28·5	23·4	18·9	15·5	14·3	12·2	10·1
		Humus freed . .	23·8	20·5	15·7	12·5	12·1	10·2	7·2
P.C. 5	7·28	Humus not freed .	25·7	23·1	15·9	13·5	15·8	14·6	11·2
		Humus freed . .	18·5	16·8	11·5	7·6	10·0	10·3	6·6
P.C. 6	4·67	Humus not freed .	30·2	..	22·9	15·2	15·8	14·4	11·8
		Humus freed . .	25·5	..	16·3	12·9	12·2	11·0	8·1

TABLE III

Humic acid after peptising it with NaOH
(*p*H of the solution = 9·3)

Particle size in mm.	Percentages
0·002	90·8
0·001	89·7
0·00063	90·2
0·0001	90·8
0·00004	90·4

PRELIMINARY ACID TREATMENTS

It has been shown elsewhere that in order to get maximum dispersion in the region of ultra-clay the methods involving acid treatments are the only ones that are most effective [Puri, Puri and Manohar Lal, 1938]. These methods, however, may be regarded as too drastic on the ground that they result in the dissolution of aluminium and iron. In order to find out how far this objection is valid, three typical soils were leached with increasing amounts of HCl of varying concentrations. The soils were afterwards washed with water until free from Cl ions and then dispersed by the addition of sufficient NaOH to bring the *p*H value of the suspensions to 10·8 and shaking overnight. The results given in Table IV clearly show that even after the removal of exchangeable bases prolonged leaching of the soil with the acid of much higher strength than that generally recommended for the purpose will produce no change in the results of ultra-mechanical analysis. The soil colloids, in fact, as far as can be judged from the behaviour of these three typical soils, are quite stable and resist the action of dilute HCl leaching. Leaching with N. HCl however, produces slight changes, but acid of this strength is never recommended in any preliminary treatment for dispersion.

HEATING SOILS TO VARIOUS TEMPERATURES

Effect of heating soils to various temperatures on their physico-chemical properties has been studied by Puri and Asghar [1940]. They found that heating at 400°C. causes fusion of clay particles resulting in the formation of stable aggregates which could not be distinguished from coarser fractions. As at temperatures below 400°C., the summation curves showed general similarity in the region of clay, silt and sand and it was at 400°C. and above this temperature that shift in the curve as a whole was noticed, this temperature (400°C.) was regarded by these authors as the 'fusion temperature of colloidal particles'*. This statement could only be justified if ultra-mechanical analysis, i.e. the analysis within the colloidal region itself could be shown to have been not affected below this temperature. Because it is quite likely that the ultra-clay might be affected even at a much lower temperature than 400°C.

Two acid-treated soils, P. C. 13 and 123 (one of which, namely, P.C. 13, was the same as that used by Puri and Asghar [1940]) were heated to various temperatures and then dispersed by the addition of enough NaOH to bring the *p*H value of the suspensions to 10·8. The results of complete mechanical and ultra-mechanical analysis are shown in Tables V and VI. It would be seen that while heating up to 300°C. has produced no difference up to 0·001 mm., it has appreciably affected the finer fractions, the effect becoming more and more pronounced as we go farther and farther into the regions of ultra-clay.

Heating up to 100°C. produces no alteration even in the region of ultra-clay but heating above this temperature tells its effect. It starts cementing finest particles first and with further rise of temperature particles coarser and coarser begin to aggregate together. We may thus regard heating the soil even at 200°C. to cause the 'fusion of colloidal particles'. It would also be seen that in the case of P. C. 123 not only abrupt change in clay percentage appears at 500°C. (instead of at 400°C. as in case of P. C. 13) but also the differences in the regions of ultra-clay are less pronounced for temperatures below 500°C. Since this soil is less colloidal in properties than P. C. 13 soil, this difference, which is of degree only, is to be expected.

As a result of 'fusion' of colloidal and coarser particles the specific surface of the soils on heating will decrease considerably. The values of specific surface of these soils at different temperatures are given in Table VII. The methods of calculating specific surface are discussed elsewhere [Puri, Balwant Rai and Malhotra, 1944].

*It must be understood that the word 'fusion' is used only in a special sense namely, cementing together of the particles

TABLE IV

Effect of preliminary acid treatments

Description of the sample	Percentages of particles below various limiting diameters in mm.						
	0·002	0·001	0·00063	0·00025	0·0001	0·00006	0·00004
P. C. 6 Soil leached with N/20 HCl till free from exchangeable bases	33·8	31·3	28·2	23·4	18·2	17·0	14·5
P. C. 6 Soil leached with N/20 HCl till free from exchangeable bases further leached with 500 cc. of N/20 HCl	34·2	32·2	29·8	24·5	18·2	18·8	14·2
P. C. 6 Soil leached with N/20 HCl till free from exchangeable bases further leached with 1000 cc. of N/20 HCl	34·8	32·4	29·6	24·9	19·1	17·2	14·6
P.C. 6 Soe leached with N/20 HCl till free from exchan able bases further leached with 500 cc. of N/5 Cl	34·4	32·1	29·0	25·1	18·5	16·9	13·8
P.C. 6 Soil leached with N/20 HCl till free from exchangeable bases further leached with 1000 cc. of N/5 HCl	33·7	32·2	29·4	24·6	17·8	16·8	14·4
P.C. 6 Soil leached with N/20 HCl till free from exchangeable bases further leached with 500 cc. of N-HCl	33·5	31·2	28·2	23·2	16·0	15·4	12·6
P.C. 6 Soil leached with N/20 HCl till free from exchangeable bases further leached with 1000 cc. of N.HCl	32·4	31·0	26·6	23·5	15·6	14·5	12·6
P.C. 13 Soil leached with N/20 HCl till freed from bases	60·1	57·7	52·5	49·0	41·5	36·7	27·2
P.C. 13 Soil leached with N/20 HCl till freed from bases further leached with 500 c.c. of N/20 HCl	60·5	56·0	51·4	48·6	40·8	36·2	28·1
P.C. 13 Soil leached with N/20 HCl till freed from bases further leached with 1000 cc. of N/20 HCl	61·5	56·6	52·2	49·2	44·0	36·4	27·8
P.C. 13 Soil leached with N/20 HCl till freed from bases further leached with 500 cc. of N/5 HCl	59·8	56·2	52·0	48·2	41·4	36·6	27·1
P.C. 13 Soil leached with N/20 HCl till freed from bases further leached with 1000 cc. of N/5 HCl	58·7	55·8	50·8	46·2	39·5	34·5	26·6
P.C. 13 Soil leached with N/20 HCl till freed from bases further leached with 500 cc. of N.HCl	56·9	54·8	49·4	45·8	40·0	31·8	25·2
P.C. 13 Soil leached with N/20 HCl till freed from bases further leached with 1000 cc. of N-HCl	57·4	55·1	49·2	45·8	39·6	31·6	25·5
P.C. 123 Soil leached with N/20 HCl till freed from bases	85·5	84·2	74·4	52·5	25·8	14·2	12·9
P.C. 123 Soil leached with N/20 HCl till freed from bases further leached with 500 cc. of N/20 HCl	84·6	83·6	74·0	49·4	24·2	13·5	11·5
P.C. 123 Soil leached with N/20 HCl till freed from bases further leached with 1000 cc. of N/20 HCl	83·8	82·0	72·6	46·2	22·2	14·0	12·6
P.C. 123 Soil leached with N/20 HCl till freed from bases further leached with 500 cc. of N/5 HCl	86·2	83·6	74·2	48·8	24·6	14·5	13·0
P.C. 123 Soil leached with N/20 HCl till freed from bases further leached with 1000 cc. of N/5 HCl	86·0	91·0	72·0	48·6	26·2	13·5	12·0
P.C. 123 Soil leached with N/20 HCl till freed from bases further leached with 500 cc. of N-HCl	80·1	79·3	69·8	44·1	23·5	12·1	10·3
P.C. 123 Soil leached with N/20 HCl till freed from bases further leached with 1000 cc. of N-HCl	78·2	75·3	63·8	42·6	23·0	12·0	10·1

TABLE V

Effect of igniting P.C. 13 A.T. soil to various temperatures

Description of the sample	Percentages of various limiting diameters in mm.										
	0·06	0·02	0·01	0·005	0·002	0·001	0·00063	0·00025	0·0001	0·00006	0·00004
1. Air-dried sample	90·8	82·8	70·6	63·6	60·3	57·7	52·9	49·2	41·0	35·7	27·2
2. Heated to 100°C.	89·5	82·9	72·2	65·0	59·2	56·7	54·4	49·1	43·2	37·9	28·2
3. Heated to 200°C.	91·4	82·5	73·5	66·2	61·2	57·2	54·2	41·7	27·2	22·1	19·2
4. Heated to 300°C.	90·8	82·7	72·8	65·2	57·5	54·4	49·6	36·5	17·3	16·0	11·2
5. Heated to 400°C.	61·8	41·4	30·2	24·5	19·5	18·2	16·4	14·7	13·5	11·0	19·5
6. Heated to 500°C.	45·6	26·2	19·1	14·1	11·2	8·4	7·6	6·3	4·8	4·5	3·9
7. Heated to 600°C.	45·5	22·6	16·4	12·2	8·5	6·8	5·4	5·5	3·4	2·9	2·5
8. Heated to 700°C.	41·0	21·2	15·4	10·6	6·0	5·4	5·0	4·2	2·8	2·2	1·7
9. Heated to 800°C.	41·0	22·2	14·7	10·5	6·5	5·8	5·2	2·8	2·4	1·9	1·0
10. Heated to 900°C.	40·5	18·2	11·9	8·2	6·4	4·2	3·2	1·2	0·9	*nil*	*nil*

TABLE VI

Effect of heating P.C. 123 A.T. to various temperatures

Description of the sample	Percentages of various limiting diameters in mm.										
	0·06	0·02	0·01	0·005	0·002	0·001	0·00063	0·00025	0·0001	0·000063	0·00004
1. Air-dried sample (No heating)	98·8	93·2	90·2	89·3	85·5	81·5	74·2	52·2	25·8	18·6	12·4
2. Heated to 100°C.	99·2	91·2	89·1	86·4	86·9	81·6	73·6	50·8	25·5	18·3	12·8
3. Heated to 200°C.	99·0	91·2	89·6	87·8	86·6	81·8	75·0	52·3	22·0	16·2	11·9
4. Heated to 300°C.	99·0	92·5	90·8	90·0	85·9	77·4	70·0	47·0	20·5	14·2	10·5
5. Heated to 400°C.	97·0	92·6	90·4	86·8	80·9	68·9	54·5	28·5	16·8	11·2	7·5
6. Heated to 500°C.	72·8	52·8	45·2	39·2	20·5	26·6	21·6	13·6	10·5	9·0	7·0
7. Heated to 600°C.	61·2	36·2	29·1	23·8	17·8	16·0	12·6	9·4	6·6	5·1	4·6
8. Heated to 700°C.	52·4	29·0	20·4	16·2	9·5	9·2	5·8	5·1	4·1	3·9	3·2
9. Heated to 800°C.	48·1	25·2	17·1	14·0	7·8	5·9	3·8	3·6	3·5	3·2	2·6
10. Heated to 900°C.	45·6	22·4	14·8	11·0	4·8	4·1	3·6	3·0	2·6	2·2	1·8

TABLE VII

Specific surface of P. C. 13 and 123 soils when heated to different temperatures

Temperature to which heated	Specific surface in sq. cm. × 10^4	
	P.C.13A.T	P.C.123A.T
Air-dried	37·5	23·7
100°C.	38·2	23·7
200°C.	26·6	22·3
300°C.	18·0	20·3
400°C.	12·3	15·2
500°C.	4·9	10·4
600°C.	3·3	6·4
700°C.	2·4	4·2
800°C.	1·8	3·3
900°C.	0·6	2·4

DISPERSION OF IGNITED SOILS AT *p*H VALUES LOWER THAN 10·8

It will be seen from Table V that samples of P. C. 13 (acid-treated) heated at 100°C., 200°C. and 300°C. when dispersed at *p*H 10·8 give almost identical values for clay percentage. In order to find out whether these samples will also disperse to equal extents at *p*H levels lower than 10·8, their 2 per cent suspensions were prepared and increasing amounts of N. NaOH were added after every 48 hours. After each addition the cylinders were shaken by hand just for a couple of minutes and then kept aside for 48 hours, after which percentage of clay (0·002 mm.) was determined by the Chaino-hydrometer [Puri and Puri, 1939]. The result recorded in Table VIII show that at low *p*H values there is difference in clay percentage which decreases with the rise in *p*H value till it disappears at the

proper *p*H level (10·8). This behaviour may be expected since the aggregation of ultra-clay particles which has been shown to take place at 200°C. and above would tend to inhibit dispersion to a certain extent. But as soon as *p*H of the suspension is raised to 10·8, the discrepancy in dispersion, as measured on the basis of conventional clay, disappears. This fact incidently suggests the significance to a marked degree of bringing the *p*H of the suspensions to 10·8 in order to get maximum dispersion [Puri and Manohar Lal, 1938].

Effect of grinding on dispersion

Grinding was one of the earliest methods of dispersion. In the present experiments P.C. 13 acid-treated soil was subjected to grinding in a pestle and mortar for different intervals of time varying from 15 min. to 12 hr. The ground material in every case was brought to *p*H 10·8 by the addition of NaOH and shaken overnight. The results of mechanical and ultra-mechanical analysis are recorded in Table IX. It is seen that silt and clay particles are considerably affected by grinding while the ultra-clay fractions up to 0·00025 mm. undergo only slight increase and fractions finer than this remain practically unchanged.

Table VIII

Dispersion of P.C. 13 A.T. heated to different temperatures on the gradual addition of increasing amounts of NaOH

[Percentage of clay (<0·002 mm.) at various temperatures]

Quantity of N. NaOH added to 12 gm. of soil (per cent suspension)	100°C.	200°C.	300°C.
0·0 c.c.	4·4	2·6	2·0
3·0 c.c.	4·8	3·0	2·4
6·0 c.c.	4·8	2·8	3·0
9·0 c.c.	9·4	5·8	3·2
12·0 c.c.	15·0	11·2	4·0
15·0 c.c.	22·6	19·7	10·5
18·0 (*p*H 10·8)	39·2	38·4	35·9
21·0 c.c.	55·6	56·0	56·2
24·0 c.c.	63·2	62·2	62·0
27·0 c.c.	63·2	61·6	64·1
30·0 c.c.	63·6	62·3	64·1
33·0 c.c.	63·8	63·4	64·5
36·0 c.c.	64·6	65·2	64·9

Table IX

Effect of grinding on mechanical and ultra-mechanical analysis
(P.C. 13 A.T.)

Time of grinding	Percentages of various limiting diameters in mm.										
	0·06	0·02	0·01	0·005	0·002	0·001	0·00063	0·00025	0·0001	0·000063	0·00004
0 min.	85·5	82·2	72·5	65·0	60·5	56·6	52·5	48·5	43·8	37·4	27·2
15 min.	90·5	85·1	74·2	69·2	63·6	60·4	53·9	52·7	44·3	39·9	27·9
30 min.	94·1	89·2	78·5	70·8	65·2	61·6	57·3	53·3	43·9	35·8	28·3
1 hour	95·5	91·5	80·4	71·4	67·8	62·8	56·5	52·8	42·8	37·2	28·6
3 hours	96·0	94·2	85·5	76·0	74·5	63·8	60·3	54·5	41·4	34·8	29·1
6 hours	96·0	94·8	92·8	80·2	76·9	67·5	59·3	54·6	42·7	36·2	27·0
12 hours	99·2	96·8	94·6	86·5	81·6	69·2	59·5	55·0	42·5	36·6	26·8

Table X

Specific surface, base exchange capacity and ammonia absorption of P.C. 13 A.T. soil after grinding for various intervals of time

Time of grinding	Specific surface in sq. cm. $\times 10^4$	Base exchange capacity (milli. equivalents per 100 gm. of soil)	Ammonia absorption (m. equivalents per 100 gm. of soil)
0 min.	37·5	42·3	30·5
15 min.	38·1	43·1	34·5
30 min.	38·9	43·3	36·2
1 hour	38·7	43·6	39·2
3 hours	38·7	44·6	41·6
6 hours	38·8	46·2	41·9
12 hours	38·8	..	..

The values for specific surface are given in Table X. There is little or no change in surface as this depends to a marked extent on the ultra-clay fractions. There is, however, appreciable increase in the ammonia absorption and some slight increase in the base exchange capacity (Table X). This is probably due to the fact that as coarser fractions are broken down to finer ones, fresh surface are exposed leading to an increase in base exchange properties.

References

Robinson, G. W. (1932). Note on the mechanical analysis of humus soils. *J. agric. Sci.* **12**, 287-91

Crowther, E. M. and Troell, E. (1932). Oxidation of organic matter in the pretreatment of soil for mechanical analysis. *Proc. 2nd Inter. Cong. Soil Sci.* **1**, 48-51

Chakraborty, J. N. (1935). The mechanical analysis of lateritic soils, III. A new method using alkaline permanganate for oxidation of organic matter. *Indian J. agric. Sci.* **5**, 41-50

Puri, A. N. and Sarup, A. (1937, 1). The destruction of organic matter in the preliminary treatment of soils for mechanical analysis. *Soil Sci.* **44**, 87-9

———————— (1937, 2). Studies in soil humus, I. Estimation of soil humus by oxidation with alkaline permanganate. *Soil Sci.* **44**, 323-7

———————— and Manohar Lal (1938). Dispersion and stability of soil colloids, I. Auto-disintegration. *Punjab Irri. Res. Pub., Vol. 4*, No. 10

———————— and Asghar, A. G. (1940). Physical characteristics of soils, VII. Effect of ignition. *Soil Sci.* **49**, 369-78

Puri, A. N., Puri, B. R. and Manohar Lal (1938). Dispersion and stability of soil colloids in water, II. Ultra-clay and the efficiency of dispersion methods. *Punjab Irri. Res. Pub., Vol. 4*, No. 11

———————— (1939). Physical characteristics of soil, IV. Density gradients in sedimenting columns and a Chaino-hydrometer for mechanical analysis of soils. *Soil Sci.* **48**, 149

———————— (1941). Ultra-mechanical analysis of soil. *J. agric. Sci.* **31**, II, 171-77

———————— Balwant Rai and Malhotra, J. K. (1944). Relation between specific surface and physico-chemical properties of soils. *Proc. Lahore Phil. Soc.*, **6**, 54-67

VARIATION IN THE MEASURABLE CHARACTERS OF COTTON FIBRES VII*

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(A) VARIATION DUE TO IRRIGATION

In the development of the cotton fibre there exist two distinct stages (1) the lengthening phase and (2) the thickening phase. The former covers approximately the first half of the maturation period of the boll and the latter the other half. According to Balls [1930] and others, if during any of these stages a deficiency in the water supply is experienced, the fibres will get either shorter or less thickened according to the occurrence of the water shortage in the lengthening or thickening stages. Hence on *a priori* considerations it appears as if the differences in the water given in the form of irrigation should influence the length, the uniformity of length and the maturity of the fibre. An attempt to study this effect is made in the present work. Recently, Ayyar, Ahmad and Thirumalachari [1940] have shown that considerable differences are effected in the yield of cotton by differential irrigation. Its influence on the spinning value and the fibre properties, however, is not found to be large.

Material and methods

In this study two sets of experiments have been considered on the cotton Co2 (*G. hirsutum*), the first being a field experiment in random replicated plots and the second one a pot-culture experiment. In the field experiment four types of irrigation were given, (i) once a week, (ii) once in two weeks, (iii) once in three weeks, and (iv) no irrigation. In each irrigational treatment three spacings, 4 in. between plants, 9 in., and broadcast sowing were tried. Two such series were studied in the present investigation.

The pot-culture experiment was conducted by Mr N.C. Thirumalachari, to whom thanks are due for the samples. Five replications have been examined for each of the following five treatments : (i) 30 per cent water for first five fortnights, 35 per cent for next four fortnights and 20 per cent afterwards ; (ii) 30 per cent for first nine fortnights, and 20 per cent afterwards ; (iii) 25 per cent for two fortnights, 35 per cent for seven fortnights and 20 per cent afterwards ; (iv) 25 per cent for two fortnights, 35 per cent for five fortnights and 20 per cent afterwards ; (v) 25 per cent for first two fortnights, 35 per cent for three fortnights and 20 per cent afterwards.

In the first investigation the fibre properties studied are the fibre length, uniformity of length and fibre maturity. The uniformity of length was assessed by the coefficient of variation of the Balls sorter length distribution. In order that this may be ascertained more accurately the group-length interval was made finer, 1/16 in. in place of the usual 1/8 in. In the pot-culture experiment, besides the above-mentioned properties, the fibre weight was also determined. The maturity was determined by examining five tufts of about 100 fibres each while in the previous case 10 such tufts were tested. The analysis of variance for the maturity percentages was made using the inverse sine transformation.

The results from the two experiments are considered together.

Results

The mean values obtained are given in Table I and the individual results along with the analysis of variance are recorded in Tables II to V.

*Part of a thesis approved for the award of D.Sc. degree by the University of Madras

(*a*) *Mean fibre length*

In both the experiments the variance due to variations in the water supplied to the plants is non-significant (Table II). But in both of them the last treatment, which corresponds to the lowest amount of water given, records the lowest mean fibre length, though according to the statistical analysis the decrease is not significant. This treatment in the pot-culture experiment corresponds to 20 per cent water after the first five fortnights. As the lengthening phase of the fibres occurs during this period, the results may be taken as an indication that probably 20 per cent water is not sufficient to develop the fibres to the optimum length. Ayyar, *et al.* [1940] have also found that the influence of differential irrigation on fibre length is small in a similar set of samples. Afzal and Ahmad [1942] find a small improvement of length with more irrigation water in the case of P. A. 4F.

A comparison of the residual errors in the two experiments shows that it is considerably more in the pot-culture experiment, indicating the higher variability exhibited by this kind of work.

(*b*) *Uniformity of fibre length*

As it is not valid to analyse the results for the coefficient of variation by the method of variance, the mean values alone may be considered. It will be seen that in the field experiment no-irrigation treatment exhibits a higher coefficient of variation of length. In the pot-culture experiment, on the other hand, there appears to be no definite trend in relation to the quantity of water given.

TABLE I

Variation with irrigation

(Mean of 6 values in Expt. 1 and of 5 values in Expt. 2)

Property	Expt. No.	Treatments				
		I	II	III	IV	V
Mean length (in.)	1	0·94	0·92	0·92	0·90	..
	2	0·90	0·91	0·90	0·91	0·84
Coefficient of variation of length (per cent)	1	21·4	22·3	22·3	23·6	..
	2	20·7	18·9	21·9	20·9	19·8
Fibre weight per cm. 10^{-6} gm.	..	..	..	..	..	..
	2	1·70	1·76	1·69	1·67	1·79
Mature fibres per cent	1	52	52	52	48	..
	2	62	67	63	62	73
Immature fibres per cent	1	16	19	18	20	..
	2	15	13	17	16	11

(*c*) *Fibre weight per cm.*

These results have been obtained for the pot-culture experiment only.

They show that the variance due to treatments is non-significant (Table IV). The differences between the mean values are also small, showing that the range of water supply dealt with in the present enquiry has induced no differential effect on the fibre weight. Ayyar, *et al.* [1940] find small improvement in fibre weight with increase of irrigation water, but Afzal and Ahmad [1942] find no significant effect in the case of P. A. 4F.

(*d*) *Fibre maturity*

In both the experiments the variation due to change in water supplied is not significant (Table V), indicating that the fibre maturity remains unaffected in the present case. Ayyar, *et al.* [1940], however, observe slight improvement of maturity with better water supply. Gulati [1941] finds an improvement of maturity with greater irrigation in the later sowings and no effect in the earlier sowings. Afzal and Ahmad [1942] find that P. A. 4F. showed a tendency for the improvement of fibre maturity with increase of water supplied.

CONCLUSIONS

From the foregoing it appears that in the present set of samples,

(1) the lowest supply of water probably tends to reduce the mean fibre length to a small extent, though it is not statistically significant ;

(2) the uniformity of fibre length appears to be less in plots with no irrigation in the field experiment; in the pot-culture experiment no definite trend is indicated;
(3) hardly any variation is effected in the fibre weight; and
(4) no variation is caused in the fibre maturity also.

Campbell, *et al.* [1941], who studied a number of Upland cottons grown under rain-fed and irrigated conditions, sum up by stating that on the whole it appears that any superiority of rain-grown cotton is chiefly connected with cleanliness; these cottons are less wasty and the yarns and fabrics are less neppy.

TABLE II

Mean fibre length in inch

Treatment → / Particulars ↓		I	II	III	IV	V	Analysis of variance: Due to	D. F.	S. S.	M. S.
Field Expt.	4 in. 1	0·95	0·91	0·89	0·92	..	Total	23	0·01793	..
	2	0·89	0·98	0·95	0·93	..	Irrigation and no irrigation	1	0·00222	0·00222
	9 in. 1	0·92	0·95	0·92	0·89	..	Irrigations	2	0·00041	0·00020
	2	0·97	0·89	0·97	0·91	..	Spacings	2	0·00083	0·00042
	Broadcast 1	0·94	0·90	0·92	0·88	..	Series	1	0·00135	0·00135
	2	0·94	0·91	0·92	0·91	..	Residual	17	0·01312	0·000772
	Mean	0·936	0·922	0·919	0·902	..				
Pot-culture Expt.	1	0·95	0·93	0·95	0·93	0·79				
	2	0·92	0·86	0·90	0·90	0·72	Total	24	0·05900	..
	3	0·87	0·86	0·82	0·87	0·87	Between treatments	4	0·01876	0·00469
	4	0·94	0·96	0·95	0·93	0·88				
	5	0·83	0·94	0·86	0·90	0·82	Within treatments	20	0·04024	0·002012
	Mean	0·902	0·910	0·896	0·906	0·836				

TABLE III

Coefficient of variation of fibre length (per cent)

Treatments → / Particulars ↓			I	II	III	IV	V
Field Expt.	4 in.	1	20·8	22·5	24·0	23·0	..
		2	23·6	20·7	22·2	22·2	..
	9 in.	1	21·8	21·2	22·4	25·3	..
		2	20·4	23·3	22·2	22·7	..
	Broadcast	1	21·2	23·3	21·7	25·3	..
		2	20·4	22·6	21·4	23·1	..
	Mean		21·37	22·27	22·32	23·60	..
Pot-culture Expt.	Rep.	1	18·6	19·1	21·2	22·3	18·6
		2	21·6	17·1	22·1	20·2	20·7
		3	22·2	20·5	21·7	20·5	21·0
		4	19·7	18·1	20·9	20·9	19·7
		5	21·3	19·7	23·4	20·5	18·9
	Mean		20·68	18·90	21·86	20·88	19·78

(B) VARIATION DUE TO SPACING

Three kinds of spacings 4 in., 9 in. and broadcast sowing were tried for the cotton Co2 in each of the four irrigational treatments as already stated. The mean values for the spacings are recorded in Table VI.

It will be seen that none of the properties, mean length, coefficient of variation of length or maturity indicate any variation. The variances are non-significant and the spacings considered in the experiment have produced no effect on the fibre properties studied. Ayyar, *et al.* [1940] have also observed no effect of the spacing in a similar set of samples.

TABLE IV

Fibre weight per cm. in 10^{-6} gm.

Replications	I	II	III	IV	V	Analysis of variance: Due to	D. F.	S. S.	M. S.
1	1·71	1·93	1·79	1·45	1·75	Total	24	0·52700	..
2	1·66	1·76	1·87	1·64	1·63	Between treatments	4	0·04898	0·01224
3	1·74	1·79	1·80	1·65	1·69				
4	1·64	1·71	1·31	1·69	1·86	Within treatments	20	0·47802	0·02390
5	1·73	1·62	1·66	1·93	2·00				
Mean	1·698	1·762	1·690	1·672	1·786				

TABLE V

Fibre maturity per cent

Treatments→ / Particulars ↓	I	II	III	IV	V	Analysis of variance (after inverse sine transformation): Due to	D. F.	S. S.	M. S.
Mature fibres 4 in. 1	59·0	50·3	50·6	51·8	..	Total	23	317·120	..
2	45·9	62·1	52·9	44·7	..	Irrigation and no irrigation	1	28·502	28·502
Field Expt. 9 in. 1	42·5	53·7	49·6	42·2	..				
2	59·1	36·0	57·3	48·1	..	Irrigations	2	0·213	0·106
Broadcast 1	49·2	49·6	49·3	43·1	..	Spacings	2	22·501	11·250
2	55·3	59·2	52·6	55·1	..	Residual	18	265·904	14·772
Mean	51·8	51·8	52·0	47·5	..				
Mature fibres 1	65	73	63	51	71	Total	24	463·542	..
2	61	64	77	59	74				
Pot-culture Expt. 3	57	58	60	63	74	Between treatments	4	161·026	40·256
4	61	68	51	61	74				
5	65	68	62	75	71	Within treatments	20	302·516	15·126
Mean	61·8	66·2	62·6	61·8	72·8				
Immature fibres 4 in. 1	11·9	19·7	22·4	17·7	..	Total	23	328·898	..
2	17·0	12·3	15·7	21·4	..				
Field Expt. 9 in. 1	27·1	19·8	17·4	21·5	..	Irrigation and no irrigation	1	11·680	11·680
2	10·7	33·3	14·2	20·7	..				
Broadcast 1	16·0	17·3	22·2	22·5	..	Irrigations	2	21·278	10·639
2	13·3	13·5	16·0	14·6	..	Spacings	2	31·365	15·688
Mean	16·0	19·3	18·0	19·8	..	Residual	18	264·575	14·699
Immature fibres 1	15	9	13	23	13	Total	24	282·926	..
Pot-culture Expt. 2	17	16	9	21	11				
3	16	15	22	14	9	Between treatments	4	67·438	16·860
4	12	12	24	13	13				
5	13	11	17	10	11	Within treatments	20	215·488	10·774
Mean	14·6	12·6	17·0	16·2	11·4				

TABLE VI

Fibre characters in different spacings

Property		4 in.	9 in.	Broadcast		
Mean length (in.)		0·93	0·93	0·92	..	..
Coefficient of variation of length (per cent)		22·4	22·4	22·4	..	..
Mature fibres per cent	Expt. 1	52·1 (6 in.)	48·6 (9 in.)	51·1 (12 in.)	.. (15 in.)	.. (18 in.)
	Expt. 2	90·6	89·9	90·5	87·0	86·6
Immature fibres per cent	Expt. 1	17·2 (6 in.)	20·6 (9 in.)	17·0 (12 in.)	.. (15 in.)	.. (18 in.)
	Expt. 2	4·5	5·0	5·0	6·4	6·3

The results for the fibre maturity in another study may be considered here. The individual results are recorded in Table VII. For the cotton Kpt. 1 five spacings were given with four replications for each spacing. The spacings were 18, 15, 12, 9 and 6 in.

It will be seen that the variations are non-significant, indicating that the different spacings used have no effect on fibre maturity. Gulati [1941] has found some improvement of maturity in double spacing as against single spacing.

TABLE VII

Fibre maturity in different spacings per cent (Kpt. 1)

Maturity	Replications	18 in.	15 in.	12 in.	9 in.	6 in.	Analysis of variance (after inverse sine transformation) Due to	D. F.	S. S.	M. S.
Mature	1	81·3	79·3	91·8	90·1	92·0	Total	19	168·378	..
	2	90·5	90·4	90·5	86·0	89·4				
	3	90·6	88·5	89·1	92·3	90·6	Between treatments	3	43·546	14·515
	4	84·2	89·7	90·5	91·2	90·3	Within treatments	16	124·832	7·796
	Mean	86·6	87·0	90·5	89·9	90·6				
Immature	1	6·5	9·5	4·2	4·4	3·4	Total	19	68·308	..
	2	4·3	5·0	4·8	7·0	5·5	Between treatments	3	16·118	5·373
	3	5·1	5·4	5·9	4·0	4·2				
	4	9·3	5·3	5·0	4·6	4·9	Within treatments	16	52·190	3·262
	Mean	6·3	6·4	5·0	5·0	4·5				

Summing up it may be stated that none of the different spacings considered in the present study have caused any change in the fibre length, uniformity of length or fibre maturity.

REFERENCES

Afzal, M. and Ahmad, N. (1942). The effect of differential irrigation on the field behaviour and quality of P. A. 4F. *Proc. Ind. Sci. Cong.* **29**, 215

Ayyar, V. R., Ahmad, N. and Thirumalachari, N. C. (1940). The effect of differential irrigation and spacing on the field behaviour and quality of Cambodia, Co 2, Cotton. *Indian J. agric. Sci.* **10**, 493-521

Balls, W. L. (1930). Seed Cotton: Growth fluctuation during development. *Min. Agric. Egypt Tech. and Sci. Serv. Bull.* **101**

Campbell, M., E. *et al.* (1941). American Upland Cottons: Spinning tests: Effects of Irrigation. *Agric. Marketg. Serv. U. S. Dept. Agric.* pp. 38

Gulati, A. N. (1941). The effect of environment on fibre maturity of cotton. *Indian J. agric. Sci.* **11**, 566-79

A NEW METHOD FOR THE ESTIMATION OF SILT AND CLAY IN SOILS

THE BUOYANCY TECHNQIUE*

By MISS G. SHARADA BAI, K. S. GURURAJA DOSS† and BASRUR SANJIVA RAO‡

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(With one text-figure)

THE hydrometer technique in the mechanical analysis of soils was first introduced by Bouyoucos [1927]. In this method the estimation of soil colloids is carried out by dispersing the soil and finding out the density of the soil suspension by means of a special hydrometer, after a definite interval of time. This method has, however, many defects as is apparent from the following statement of Keen [1928]: "Hence in physical terms, the hydrometer technique consists in measuring at an arbitrary time the average density of a layer of suspension several cm. in length, whose density is continually changing with depth and time. The statement that the method is 'essentially qualitative' is not a matter of opinion but of fact."

*Part of thesis submitted by Miss G. Sharada Bai in partial fulfilment for the degree of Master of Science of the University of Mysore

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Some of these objections have been overcome by Puri [1932] in a new type of hydrometer. Recently, Puri [1939] has described another instrument 'the chaino-hydrometer' which practically removes all the objections against the hydrometer technique. The only source of error that may creep in is that the density gradient around the hydrometer bulb in the sedimenting column may not be uniform. By extensive empirical investigations, Puri has shown that the error from this source is inappreciable in most cases.

The chaino-hydrometer is, however, difficult to construct and the stem of the hydrometer cannot be made quite thin as it has to support a frame carrying the chain. The buoyancy technique described in the present paper is a logical development of the chaino-hydrometer, and yields more accurate results. A few soils have been investigated and the results obtained have been compared with those given by the pipette method.

Experimental

The international A method was employed for dispersing the soils. The soil was treated in 100 gm. lots and a large stock of the suspension prepared to avoid errors in sampling.

It was found that the soil suspension, on ageing, developed compound particles which were not broken up by the simple process of inverting the jar containing the suspension repeatedly for one minute. It was found that a preliminary shaking for 5 min. on a mechanical shaker was highly helpful in giving reproducible results. Each suspension was given this treatment prior to the determination of silt and clay.

The buoyancy technique

A cylindrical glass bulb was suspended in a sedimenting column of the soil suspension so that the centre of buoyancy of the bulb was kept at 10 cm. below the surface of the sedimenting column. After an interval of 4 min. and 10 sec. (corresponding to 26°C.), the apparent loss in weight of the bulb was determined by using the new type of continuous reading balance devised by Venkatachala, Doss and Rao*. A diagrammatic sketch of the instrument is given in Fig. 1. A balance (sensitiveness 1 mg.) had hooks B and C attached to the underside of the two scale pans. The buoyancy bulb A was suspended from the hook B by means of a fine nichrome wire which passed through a hole in the stand on which the balance was mounted. From the other hook C, was similarly suspended a glass rod D, (of uniform diameter) dipping in xylene kept in a U-tube. A side tube E attached to one of the limbs of the U-tube carried a millimeter scale on

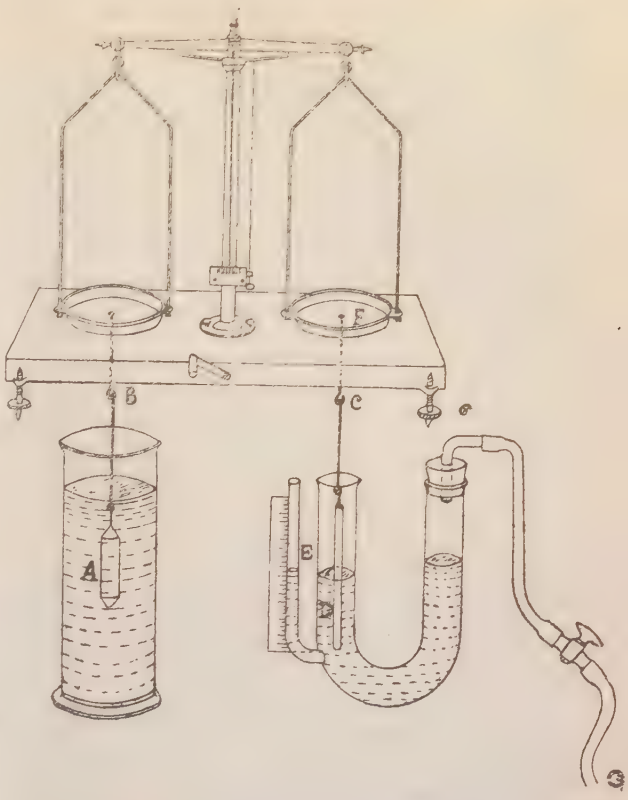

Fig. 1. Continuous reading balance (buoyancy principle)

which the level of xylene could be read. This device eliminated the use of weights smaller than 0·2 gm. in weighing. To counterpoise the buoyancy bulb, weights up to 0·2 gm. were placed in the scale pan F and the final adjustment was made by altering the level of xylene in the U-tube, by suction through G. Movements of the pointer of the balance were viewed through a lens attached to the balance. The diameter of the glass rod was such as to give an accuracy of 2 mg. which was quite adequate for present purposes. Weighings could be carried out very rapidly using this instrument.

Determination of the centre of buoyancy

The following method was adopted to find out approximately the centre of buoyancy. The buoyancy bulb was completely immersed in water kept in a narrow measuring jar and the volume of water displaced was noticed (V_2-V_1 c.c.). The bulb was then raised until the level came up to $\frac{V_2+V_1}{2} - \frac{2\pi R\gamma}{\rho g}$, where R is the radius of the cylinder, γ is the surface tension of water, ρ is the density of water and g is the acceleration due to gravity. The position of the meniscus was noted

* Unpublished

($l_1$cm.) by means of a scale. Water was then removed from the jar by suction until the water surface just touched the bulb. The new position of the meniscus was noticed ($l_2$cm.). The centre of buoyancy was l_2-l_1 cm.—above the tip of the bulb. This approximate method was adequate for most purposes.

To determine accurately the centre of buoyancy, the bulb A was counterpoised and the weight W_1 noted. The pans were then supported on wooden wedges so as to maintain the pointer at zero. A wide jar H containing distilled water (kept on a rising table stand), was placed under the bulb and adjusted till the bulb was completely immersed. The pan supports were then removed and the bulb again counterpoised (weight W_2). A weight equal to $\frac{W_1 - W_2}{2} + \frac{2\pi R\gamma}{g}$ was then added on to the right hand pan. The jar was then lowered until there was equilibrium. The surface of water in the jar would now be at the centre of buoyancy of the bulb. The distance between this surface of water and the bottom tip of the bulb A was measured by means of a cathetometer. A millimetre scale can be used in place of the cathetometer and is quite sufficient for most purposes

The results obtained by the graphical method of Puri [1939] and the methods herein described have been in close agreement. Both the new methods described above are simple, and quick. They can, moreover, be used with a bulb which is not symmetrical about the vertical axis while such symmetry is essential for the graphical method.

The silt and clay contents have been calculated using the formula :

$$\text{Wt. of soil (silt or clay) in gm. per 100 c.c. of suspension} = \frac{\text{loss of wt. under soil suspension} - \text{loss of wt. under dispersion medium}}{\text{loss of wt. under water}} \times \text{Density of water} \times 0{\cdot}006269$$

To find out the amount of clay, the buoyancy was determined after 7 hr. of sedimentation at 26°C. at a depth of 10 cm. Four soils were examined for their silt and clay contents by (*a*) the pipette method and (*b*) the buoyancy technique. The results are given in Tables I and II.

TABLE I

Silt+Clay in 100 gm. of soil

No. of the soil	Pipette method: Average of five determinations	Pipette method: Average error	Buoyancy technique: Bulb 1: Average of five determinations—Depth 10 cm.	Bulb 1: Average error	Bulb 1: Average of five determinations—Depth 12·5 cm.	Bulb 1: Average error	Bulb 2: Average of five determinations—Depth 10 cm.	Bulb 2: Average error	Bulb 3: Average of five determinations—Depth 10 cm.	Bulb 3: Average error
1	31·8	0·6	32·7	0·05	32·9	0·05	33·3	0·01	30·7	0·01
2	25·2	0·1*	27·2	0·07	25·4	0·02	..	..	25·4	0·03
3	49·3	0·7	49·3	0·09	49·9	0·08	49·1	0·03	52·3	0·05
4	29·1	0·6	31·7	0·05	29·1	0·10	..	..	29·1	0·05

*This low error is unusual

Soils 1 and 2 were ' red soils ' from the Government Agricultural Farm, Hebbal, (Bangalore)
Soils 3 and 4 were ' black cotton ' soils from the Government Experimental Farm, Hiriyur (Mysore State)

TABLE II

Amount of clay in 100 gm. of soil

No. of the soil	Pipette method	Buoyancy method
1	28·4	30·7
2	22·7	23·8
3	0·75	1·1
4	1·44	2·5

DISCUSSION

An examination of Table I shows that the average error in the buoyancy measurements by the present technique is hardly 0·1 per cent in the value of the percentage of silt and clay. The pipette method, however, has an average error of 0·7 per cent. The differences in values obtained, when bulbs of different sizes are employed, are presumably due to non-uniformity in density gradients existing in the suspensions examined. These differences are rather high but are still

of the same order as the errors in sampling. The buoyancy technique can therefore be conveniently employed for mechanical analysis, in place of the rather laborious pipette method especially when quickness and moderate accuracy are aimed at. The buoyancy method is more accurate than the hydrometer technique. Theoretically, the former technique corresponds to a chaino-hydrometer with an exceedingly fine stem. The buoyancy bulbs are easily constructed and the experimental outfit can be readily assembled.

Use of the Buoyancy technique to obtain complete summation curves

It is of interest to consider whether the buoyancy bulb can be employed to get the complete summation curve. A detailed theoretical consideration shows that a short cylinder with a flat bottom suspended in a suspension is exactly equivalent to a sedimentation pan placed at the level of the bottom of the cylinder, when one takes into account the combined effect of settling of the particles (*a*) around the cylinder which would affect the buoyancy and (*b*) on the top of the cylinder which would affect the weight of the cylinder. The sedimentation curve can, therefore, be obtained as in the sedimentation balance. But, the buoyancy bulb has no special advantage over the sedimentation balance.

A precision buoyancy technique

It is of interest to consider the best conditions under which the buoyancy technique would yield correct results. Let us consider a cylinder placed in a liquid column of varying density. It is well known that the buoyancy suffered by the cylinder is in no way dependent on the density of fluid above the top of the bulb or below the bottom of the bulb. It is entirely determined by the density of the liquid surrounding the bulb. On the basis of this idea, it is easy to see that the ideal conditions for the buoyancy technique are the following :

A flat cylinder is immersed into the sedimenting column at the appropriate time so that the centre of the cylindrical bulb is at the level at which the density of the suspension is to be measured. The suspension is to be contained in the jar which is just 0·5 cm. to 1 cm. wider than the diameter of the cylindrical bulb. The introduction of the cylinder stirs up the upper portions of the sedimenting column but this does not matter in the least, as already pointed out. When the centre of the bulb occupies the proper level, the liquid surrounding the bulb is contributed by a thin layer around the level corresponding to the centre of buoyancy of the bulb. Thus we get the average density of a thin layer of the suspension at the appropriate depth. This is what is aimed at by the pipette technique but is rarely achieved due to stream line effects. In this respect this modified buoyancy technique presumably surpasses even the pipette technique in precision.

There is no difficulty experimental or theoretical in adopting this technique for the determination of clay. In the determination of silt and clay, however, the particles settling over the cylinder may interfere. This difficulty can be overcome by introducing the buoyancy bulbs just at the appropriate time and taking a few measurements at intervals of 2 min. and extrapolating the value for zero time (i.e. the time of introduction of the bulb).

If a high degree of precision is not aimed at, a narrow cylindrical bulb in a wide jar is more convenient than a flat cylinder in a narrow jar.

Correct conditions for the determination of silt+clay and clay using Buoyoucos' hydrometer

An examination of the Bouyoucos' hydrometer has revealed to us that the markings on the hydrometer, though empirical as claimed by the maker, correspond exactly to the densities of the soil suspensions having the corresponding concentrations of soil. But in order that the Buoyoucos' hydrometer may be employed for the determinations of silt and clay the following procedure is to be adopted.

Let the position of the centre of buoyancy of the hydrometer be found out by the method described in this paper. Let the vertical distance between the centre of buoyancy and the zero of the hydrometer be l_1 cm. If the hydrometer is lowered into the jar (supplied with it) containing water until it is immersed up to the centre of buoyancy let the displacement of the level of the water be l_2 cm. If t_1 minutes is the time corresponding to a height of 10 cm. for the determination of clay (or silt plus clay), calculate the value of t_2 by the equation

$$t_2 = \frac{l_1+l_2}{10} \times t_1.$$

The suspension is now put into the jar up to the mark. Sedimentation is allowed to occur after shaking the suspension. At the end of $(t_2—1)$ minutes the hydrometer is introduced into the suspension, so that it floats freely. The suspension is sucked off from the top into a wash bottle by means of a filter pump until the zero of the hydrometer is at the same level as the mark on the jar (i.e. the former level of the suspension). The hydrometer reading is noted at t_2 minutes. It gives directly the number of grams of soil per litre of the suspension. A correction may be applied for the value got by putting the hydrometer in the medium in which the soil is dispersed.

The timings and procedure given by Bouyoucos are theoretically not justifiable. The above procedure removes most of the errors of the Bouyoucos' hydrometer technique. The only error which remains over is that the position of the centre of buoyancy depends upon the extent to which the hydrometer gets immersed while floating in the suspension. The error introduced on this score is, however, within the limits of accuracy of the instrument.

REFERENCES

Bouyoucos, G. J. (1927). The hydrometer as a new method for the mechanical analysis of soils. *Soil Sci.* **23**, 343-50

Keen, B. A. (1928). Some comments on the hydrometer method for studying soils. *Soil Sci.* **26**, 262

Puri, A. N. (1932). A new type of hydrometer for the mechanical analysis of soils. *Soil Sci.* **33**, 241-8

————(1939). Density gradients in sedimenting columns and a chaino-hydrometer for mechanical analysis of soils. *Soil Sci.* **38**, 149-60

SOME FUNGI FROM ASSAM, I

By S. Chowdhury, Plant Pathological Laboratory, Sylhet, Assam

(Received for publication on 4 December 1943)

In the course of the past two years the writer was able to collect a few parasitic fungi occurring both on cultivated and wild plants in some parts of Assam. Even though fungi were collected in the Khasi Hills by Hooker and Thompson early in the nineteenth century and by Butler and Subramaniam between the years 1910-15, a systematic collection of fungi in Assam has yet to be made. The nature of the country with its dense forests and heavy rainfall indicates, however, that there may be many species as yet unrecorded for India and new to science. A beginning has therefore been made in collecting and identifying them as opportunities permit. The collections listed below were identified in the *Herb. Crypt. Ind. Orient.* of the Imperial Agricultural Research Institute, New Delhi.

I. Phycomycetes

Oomycetes

Cystopus candidus (Pers.) Lév.

On the leaves and stems of *Brassica Napus* L.; Habiganj. Collected on 27 January 1943 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Phytophthora Arecae (Coleman) Pethybridge

On the leaves, fruits and peduncles of *Areca Catechu* L.; Karimganj, Tajpur. Collected on 7 December 1941 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

P. Colocasiae Raciborski

On the leaves, petioles, flowers and corms of, *Colocasia antiquorum* Schott.; Baniachong, Inathganj, Sylhet. Collected on 7 October 1941 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

P. infestans de Bary

On all parts of *Solanum tuberosum* L.; Khasi Hills, Biswanath. Collected on 26 February, 1943 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

P. parasitica Dastur

On the leaves and stems of *Piper Betle* L Throughout the district of Sylhet. Collected on 7 May, 1942 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Zygomycetes

Rhizopus Artocarpi Raciborski

On the young immature fruits of *Artocarpus integrifolia* L.; throughout the province. Collected on 14 February, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

II. Ascomycetes

Hemiascomycetes

Taphrina deformans (Berk.) Tul.

On the leaves of *Prunus persica* Benth. & Hooker f.; Shillong. Collected on 7 August, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

T. maculans Butler

On the leaves of *Curcuma longa* L.; Sylhet, Maulvibazar. Collected on 10 November, 1941 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Pyrenomycetes

Erysiphe Polygoni DC.

On the leaves of *Pisum sativum* L.; Sylhet. Collected on 17 February, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

eliola palmicola Wint.

On the leaves of *Phoenix sylvestris* Roxb.; rhat, Sibsagar. Collected on 19 May, 1943 and pt in the *Herb. Crypt. Ind. Orient.* and in the erbarium of the Plant Pathological Laboratory, lhet.

stilaginoidea virens (Cke) Takahashi.

In the inflorescence of *Oryza sativa* L.; Karimnj, Habiganj, Inathganj, Jagatsi. Collected on November, 1941 and kept in the *Herb. Crypt. d. Orient.* and in the Herbarium of the Plant thological Laboratory, Sylhet.

III. Basidiomycetes

Ustilaginales

stilago Cynodontis P. Henn.

In the inflorescence of *Cynodon Dactylon* Pers. ulaura, Duttgram. Collected on 2 January, 42 and kept in the Herbarium of the Plant thological Laboratory, Sylhet.

. *Hordei* (Pers.) Lagerheim

In the ovaries of *Hordeum vulgare* L.; Dullocherra, Jorhat. Collected on 2 March, 1942 and ept in the Herbarium of the Plant Pathological aboratory, Sylhet.

. *nuda* (Jensen) Rostrup

In the inflorescences of *Hordeaum vulgare* L.; orhat. Collected on 2 February, 1942 and kept the Herbarium of the Plant Pathological Laboatory, Sylhet.

. *scitaminea* Syd.

In the culms of *Saccharum officinarum* Bhanugach, Kamalpur. Collected on 25 March, 943 and kept in the Herbarium of the Plant athological Laboratory, Sylhet.

. *Coicis* Bref.

In ovaries of Coix Lachryma-jobi L.; Shillong. ollected on 10 September, 1942 and kept in the erb. *Crypt. Ind. Orient.* and in the Herbarium the Plant Pathological Laboratory, Sylhet.

. *Tritici* (Pers.) Rostrup

In ovaries of *Triticum vulgare* Host; Dullocherra, Jorhat. Collected on 2 February, 1943 nd kept in the Herbarium of the Plant Pathogical Laboratory, Sylhet.

. *Utriculosa* (Nees) Tul.

In the ovaries of *Polygonum orientale* L. The ngus has not been previously recorded on this ost in India and as far known, from elsewhere; akhipur. Binnakandi. Collected on 27 Febuary, 1941 and kept in the *Herb. Crypt. Ind. rient.* and in the Herbarium of the Plant Pathogical Laboratory, Sylhet.

Graphiola applanata Syd. & Butler

In living leaves of *Phoenix sylvestris* Roxb. Habiganj, Maulvibazar. Collected on 1 February, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Sphacelotheca Rottboelliae (Syd. & Butler) Mundkur

In spikes of *Rottboellia protensa* Hack. The fungus has not been previously recorded on this host; Habiganj. Collected on 7 March, 1943 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Cintractia Mundkuri Chowdhury n. sp.

Sori at the base of flower stalks, forming compact black roundish swellings, at first covered by a whitish false membrane, which soon flakes away exposing dark coloured spore masses. Spore masses amorphous, forming agglutinated more or less firm mass of spores. Spores spherical, yellowish brown, 11·6 to 15·8 μ (mean 13·4μ) with thick exospore and highly granular cell contents, giving the spores a reticulate appearance.

At the base of floral stalks of *Fimbristylis diphylla* Vahl.; Habiganj. 7 March, 1942. Collected by S. Chowdhury.

Type specimen deposited in the *Herb. Crypt. Ind. Orient.* New Delhi *Cintractia Mundkuri* Chowdhury sp. nov.

Sori ad basim florum inveniuntur, formantes alveolos densos, nigros et sub-rotundos, primum sub-albo falso membrano tectos, qui mox cadens spororum massas atras exponit. Haemassae sunt amosphàéet plus minusve agglutinatae. Spori rotundi, flavo-mauri coloris, 11·6—15·8 μ (med. 13 4 μ) cum exosporo crasso et valde granularibus cellulis composito, et faciens sporos reticulatos in apparentia.

Ad basim florum *Fimbristylis diphyllae* Vahl. Habiganj 7 Martii, 42 Leg. S. Chowdhury.

Specimen typicum depositum in *Herb. Crypt. Ind. Orient.* Nova Delhi.

Tilletia horrida Takahashi

In the grains of *Oryza sativa* L., throughout the province. Collected on 17 December, 1942 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Uredinales

Melampsora Lini (Pers.) Lev.

On the leaves and stems of *Linum usitatissimum* L.; Habiganj. Collected on 7 March, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Puccinia graminis Pers.

On the stems and leaves of *Triticum vulgare* Host; Dullabcherra. Collected on 10 March, 1943 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

P. glumarum (Schm.) Erikss. & Henn.

On the leaves and culms of *Triticum vulgare* Host; Dullabcherra. Collected on 8 February, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

P. scirpi DC.

Uredo and teleuto stages on leaves of *Scirpus articulatus* L.; Kasba. Collected on 21 December, 1942 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Uromyces Fabae (Pers.) de Bary

On the leaves, stems and pods of *Pisum sativum* L.; Sylhet. Collected on 17 February, 1942 and kept in the *Herb. Crypt. Ind. Orient.* and in the Herbarium of the Plant Pathological Laboratory, Sylhet.

IV. Fungi Imperfecti

Hyphomycetes

Alternaria Brassicae (Berk.) Sacc.

On the leaves, stems and pods of *Brassica campestris* L. Habiganj, Karimganj. Collected on 8 January, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

A. solani (Ell & Mart.) Jones & Grout.

On the leaves of *Solanum tuberosum* L.; Sylhet, Somarai. Collected on 7 February, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet and in the *Herb. Crypt. Ind. Orient.*

Cercospora Calotropidis Ell. & Ev.

On the leaves of *Calotropis gigantea* Br.; Samshernagar. Collected on 17 February, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

C. Carthami Sundaraman & Ramkrishnan

On the leaves of *Carthamus tinctorius* L.; Hazipur, Manu. Collected on 4 March, 1943 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

C. Concors (Casp.) Sacc.

On the leaves of *Solanum tuberosum* L.; Sylhet, Basudevsri. Collected on 18 January, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

C. cruenta Sacc.

On the leaves of *Phaseolus vulgaris* L.; Kalighat, Rajnagar. Collected on 19 January, 1943 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

C. Hibisci Tracy & Earle

On the leaves of *Hibiscus sabdariffa* L.; Sylhe Collected on 20 February, 1943 and kept in th *Herb. Crypt. Ind. Orient.* and in the Herbarium the Plant Pathological Laboratory, Sylhet.

C. Occidentalis Cke.

On the leaves of *Cassia occidentalis* L.; Shaist ganj. Collected on 27 February, 1942 and kep in the Herbarium of the Plant Pathological Labo ratory, Sylhet.

C. personata (Berk. & Curt.) Ell. & Ev.

On the leaves, stems and petioles of *Arach hypogaea* L.; Sylhet. Collected on 2 July, 194 and kept in the *Herb. Crypt. Ind. Orient.* and in th Herbarium of the Plant Pathological Laboratory Sylhet.

C. Sesami Zimm.

On the leaves and stems of *Sesamum orienta* L.; Sylhet. Collected on 2 July, 1942 and kep in the *Herb. Crypt. Ind. Orient.* and in the Her barium of the Plant Pathological Laboratory Sylhet.

Fusarium moniliforme Sheld.

On the roots and culms of *Oryza sativa* L. Karimganj. Collected on 7 October, 1942 an kept in the Herbarium of the Plant Pathologic Laboratory, Sylhet.

Helminthosporium Oryzae Breda de Haan.

On the leaves of *Oryza sativa* L.; Sylhet, Inat ganj. Collected on 25 June, 1942 and kept in th *Herb. Crypt. Ind. Orient.* and in the Herbariu of the Plant Pathological Laboratory, Sylhet.

Piricularia Oryzae Cavara.

On the leaves of *Oryza sativa* L.; Akbarpu Jorhat, Titabar. Collected on 7 August, 194 and kept in the Herbarium of the Plant Patho logical Laboratory, Sylhet.

Sphaeropsidales and Melanconiales

Colletotrichum falcatum Went

On the leaves and culms of *Saccharum offici narum* L.; Sylhet, Silchar. Collected on 1 August, 1943 and kept in the Herbarium of th Plant Pathological Laboratory, Sylhet.

C. Gloeosporioides Penzig.

On *Citrus Aurantium* L.; Sylhet, Khasi Hills North Cachar Hills. Collected on 18 February 1942 and kept in the Herbarium of the Plan Pathological Laboratory, Sylhet.

C. graminicolum (Ces.) Wils.

On the leaves of *Andropogon Sorghum* Brot Katakhal. Collected on 7 July, 1942 and kep in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Diplodia Corchori Syd.

On stems of *Corchorus capsularis* L. and C *olitorius* L.; Habiganj, Agna. Collected on 1

September, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

Gloeosporium Musarum Cke & Massee

On fruits of *Musa paradisiaca* L.; Samshernagar, Kanaighat. Collected on 12 July, 1942 and kept in the Herbarium of the Plant Pathological Laboratory, Sylhet.

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ESTIMATION OF SUGARCANE TOP-BORER (*SCIRPOPHAGA NIVELLA* F.) INFESTATION

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THE extension of the area under sugarcane and the changes in the cultivation practices of this crop have brought the problem of its insect pests to the fore front. Sugarcane top-borer (*Scirpophaga nivella* F.) heads the list of these pests in India in general and the Punjab in particular. Therefore, in view of the losses inflicted by this pest on the sugarcane crop, the Entomologist, the Agronomist, and the Cane Breeder want to know (*i*) its relative abundance in different localities and extent of its damage during different years, and (*ii*) the comparative resistance of different varieties of sugarcane to it. In order to find this information it is essential to study the percentage of shoots attacked by the top-borer and to achieve this object the only method so far known is to count, separately over the whole field the entire nunber of healthy and infested shoots, and then to work out the extent of infestation therefrom. This is a very tedious, time-consuming, and costly task, particularly when the number of varieties and the areas under them are large.

The importance of a correct and a convenient method of finding the top-borer infestation can hardly be over-emphasized. Myers [1932] asserts that 'what we most clearly lack is a standard method of estimating infestation and determining damage'. The size of the sample and the number of replications should be such as to reduce the Standard Error of the data to a practical minimum : the number of canes to be counted should, consistent with efficiency, be as small as possible. The need for standardizing the technique for finding top-borer infestation is further emphasized by the fact that the spread of sugarcane top-borer does not follow any regular law of soil fertility or a topo-graphical curve. Investigations were, therefore, undertaken with Co 285 canes in order to find a suitable, convenient and, at the same time, correct method for estimating top-borer infestation in a given area. The results of these investigations are presented in this paper.

METHOD AND MATERIAL

A one-third acre field of sugarcane, Co 285, with normal stand was selected at the Sugarcane Research Station, Jullundur, and the counts were made in the field during November when the sugarcane top-borer infestation had touched the peak. The field was divided with ropes for the purpose of making the counts into 40 equal sub-plots which extended parallel to the width of the field. In each of these sub-plots all the canes were counted in separate sections of 50 canes each, and the number of top-borer affected canes in such sections was also recorded. Thus the infestation figures from 400 sections each with 50 canes were collected for statistical analysis. These figures are given in Table I.

The frequency of the number of sections which have different infestation percentages is given in Table II.

It is clear from Table II that the frequency diagram would be approximately a normal one. The statistics known as $g1$ and $g2$ were calculated to test the departure of the frequency curve from the normal. The values of these statistics were found to be—$0{\cdot}202 \pm 0{\cdot}122$ and $0{\cdot}282 \pm 0{\cdot}243$ respectively. These values indicate that the frequency curve possesses a negative skewness and is a peaked one. The values of $g1$ and $g2$, though greater than their Standard Errors, do not bring out or point to a significant deviation from normality. It is, therefore, apparent that the present technique evolved for the estimation of sugarcane top-borer infestation can be recommended to the research workers

TABLE I

Exact number of top-borer affected canes in each section of 50 canes

22	30	20	22	22	18	25	27	14	33	27	21	19	19	25	13	19	21	20	25	25	17	15	14	6	11	5	12	18	15	13	21	16	12	10	8	14	10	24	15
21	35	21	25	19	32	34	33	38	40	37	32	31	24	22	27	29	29	26	24	35	28	25	28	31	19	14	36	23	18	9	20	30	24	12	29	15	23	21	23
23	35	32	34	32	32	27	35	22	32	39	33	24	29	23	37	25	28	24	29	34	24	24	29	28	26	28	28	35	29	18	18	26	24	24	28	32	26	19	22
21	34	33	33	31	33	32	40	43	25	28	31	36	35	32	37	46	41	28	24	29	22	23	37	34	30	34	33	22	22	25	30	35	21	24	21	30	29	31	26
26	40	32	34	35	33	34	33	33	34	41	34	31	41	33	34	42	31	34	29	33	31	25	22	27	33	23	25	17	30	29	37	31	28	14	32	35	19	23	25
26	35	31	31	26	27	21	31	32	30	24	25	45	41	36	30	29	39	26	33	41	29	30	33	48	18	22	24	30	27	31	29	28	26	20	43	14	26	28	29
25	25	26	32	33	31	40	41	39	32	29	25	27	47	30	34	38	28	32	24	31	42	35	21	20	19	20	20	29	30	21	28	26	22	25	38	29	32	31	34
34	21	48	30	36	23	29	41	33	40	27	25	22	40	44	28	35	29	31	32	24	30	35	8	32	24	36	24	22	31	37	26	28	22	29	17	30	26	31	38
21	34	22	25	24	27	32	38	29	30	24	21	25	26	35	29	19	31	28	37	20	38	34	21	33	29	27	23	39	40	36	27	24	31	31	23	27	32	26	26
22	30	16	29	31	34	24	30	35	40	32	32	19	36	39	30	31	28	19	30	19	28	34	24	34	23	30	31	28	31	31	28	37	29	27	22	25	31	33	33

TABLE II

Spread of infestation in 400 sections

Infestation percentage	Number of sections which have this infestation percentage	Infestation percentage	Number of sections which have this infestation percentage
10	1	56	22
12	1	58	26
14	0	60	21
16	2	62	28
18	1	64	24
20	2	66	20
22	1	68	17
24	3	70	14
26	2	72	7
28	6	74	9
30	4	76	6
32	2	78	5
34	3	80	8
36	6	82	7
38	13	84	2
40	8	86	2
42	17	88	1
44	18	90	1
46	12	92	1
48	21	94	1
50	21	96	2
52	18		
54	14	Total	400

engaged on this problem. The lines of work detailed in the present paper should arouse similar interest amongst other workers on sugarcane entomology in India.

The infestation of 12 sample sizes, i.e., 50. 100, 200, 250, 400, 500, 800, 1,000, 1,250, 2,000 2,500 and 5000 canes taken as representative samples from a total population of 20,000 canes, were combined in all possible ways for the purpose of finding out a suitable size and shape of the sample and the number of times for which such sample should be repeated. There were thus obtained 21 different combinations and these combinations account for all the different sizes and shapes of the sample.

Experimental results

The figures of infestation percentage in the whole field of 400 sections, grouped according to the nature of the samples were analysed statistically by the following two methods, (*i*) the sum of squares due to columns and rows was not eliminated, and (*ii*) the effect of columns and rows was eliminated with a view to obtain (*a*) an average trend of the size of the sample and (*b*) figures which are neither too low nor too high.

Table III

Serial No.	Nature of the sample	No. of canes in the sample	No. of replications	Mean percentage of attack per sample	Standard deviation	Standard error on per cane basis	Co-efficient of variation	Standard error of Co-efficient of variation	Relative precision corrected for number of replications
	(Rows × Cols.)								
1	1×1 . .	50	400	56·1	14·622	2·068	26·064	0·9215	100
2	1×2 . .	100	200	56·1	11·945	1·1945	21·292	1·0646	75
3	2×1 . .	100	200	56·1	11·796	1·1796	21·027	1·0513	77
4	1×4 . .	200	100	56·1	10·324	0·7300	18·403	1·3014	50
5	2×2 . .	200	100	56·1	9·800	0·6930	17·468	1·2139	55
6	5×1 . .	250	80	56·1	9·970	0·6306	17·789	1·4063	43
7	1×5 . .	250	80	56·1	8·293	0·5245	14·782	1·1686	62
8	1×8 . .	400	50	56·1	9·219	0·4610	16·433	1·6433	31
9	2×4 . .	400	50	56·1	8·808	0·4404	15·686	1·5686	34
10	5×2 . .	500	40	56·1	8·930	0·3994	15·919	1·7798	26
11	2×5 . .	500	40	56·1	8·595	0·3844	15·321	1·7467	28
12	1×10 . .	500	40	56·1	6·538	0·2924	11·654	1·3029	49
13	2×8 . .	800	25	56·1	8·078	0·2856	14·399	2·0363	20
14	5×4 . .	1000	20	56·1	8·675	0·2743	15·454	2·4439	14
15	2×10 . .	1000	20	56·1	7·937	0·2510	14·148	2·2372	16
16	1×20 . .	1000	20	56·1	5·836	0·1845	10·403	1·6450	29
17	5×5 . .	1250	16	56·1	5·844	0·1653	10·417	1·8415	24
18	5×8 . .	2000	10	56·1	7·682	0·1718	13·684	3·0598	8
19	2×20 . .	2000	10	56·1	5·439	0·1216	9·695	2·1679	16
20	5×10 . .	2500	8	56·1	5·989	0·1198	10·675	2·6687	11
21	5×20 .	5000	4	56·1	5·807	0·0821	10·351	3·6600	5

The values of the Standard Deviation, Standard Error, the Co-efficient of Variation, Standard Error of Variance and the Relative Precision for all the 21 combinations both before and after eliminating the effects of columns and rows are given in Table III and Table IV respectively.

In Tables V and VI, the samples containing the same number of canes but with different shapes are grouped together and the average Standard Deviation, Standard Error, the Co-efficient of Variation and the Standard Error of Coefficient of Variation for each shape are worked out. It is seen from Table V that the Standard Deviation, Standard Error, and the Coefficient of Variation fall rapidly in value from a sample of 50 canes to one having 200 canes but later on the fall is gradual. The reduction in the value of these statistics from samples of 500 canes to those having 800 canes is small and the difference of these values for samples of 1000 to 2000 canes

TABTE IV

Serial No.	Nature of the sample	No. of canes in the sample	No. of replications	Mean percentage of attack per sample	Standard deviation after removing the effect of rows and columns	Standard error on per cane basis	Co-efficient of variation after removing the effect of rows and columns	Standard error of coefficient of variation	Relative precision corrected for number of replications
	(Rows × Cols.)								
1	1×1 . .	50	400	56·1	12·349	1·746	22·0107	0·7782	100
2	1×2 . .	100	200	56·1	8·809	0·8809	15·7023	0·7851	71
3	2×1 . .	100	200	56·1	9·889	0·9889	17·6112	0·8806	80
4	1×4 . .	200	100	56·1	6·805	0·4812	12·1354	0·8581	55
5	2×2 . . .	200	100	56·1	6·697	0·4736	11·9376	0.8441	54
6	5×1 . .	250	80	56·1	7·307	0·4621	13·0251	1·0298	59
7	1×5 . .	250	80	56·1	5·775	0·3653	10·2940	0·8139	47
8	1×8 . .	400	50	56·1	4·772	0·2386	8·5062	0·8506	39
9	2×4 . .	400	50	56 1	5·283	0·2642	9·4171	0·9417	43
10	5×2 . .	500	40	56·1	4·461	0·1995	7·9518	0·8890	36
11	2×5 . .	500	40	56·1	4·555	0·2037	8·1196	0·9078	37
12	1×10 . .	500	40	56·1	4·227	0·1890	7·5240	0·8412	34
13	2×8 . .	800	25	56·1	3·857	0·1364	6·8752	0·9723	31
14	5×4 . .	1000	20	56·1	4·211	0·1332	7·5062	1·1853	34
15	2×10 . .	1000	20	56·1	3·845	0·1216	6·8538	1·0837	31
16	1×20 . .	1000	20	56·1	4·211	0·1332	7·5062	1·1853	34
17	5×5 . .	1250	16	56·1	3·240	0·0916	5·7575	1·0178	26
18	5×8 . .	2000	10	56·1	3·920	0·0877	6·9875	1·5625	32
19	2×20 . .	2000	10	56·1	3·930	0·0878	7·0053	1·5664	32
20	5×10 . .	2500	8	56·1	3·142	0·0628	5·6007	1·4002	25
21	5×20 . . .	5000	4	56·1	2·900	0·0410	5·1693	1·8276	23

In order to obtain the suitable size and shape of the samples the data in Tables III and IV were arranged in the form of Tables V and VI respectively

is again very little and it may therefore be inferred that the Standard Error and the Coefficient of Variation do not fall appreciably if the size of the sample is increased from 1000 to 2000 canes. Table VI also leads to similar inferences. Thus it can be safely concluded that from the point of view of precision there appears to be very little advantage in increasing the size of the sample beyond 500 canes.

Another interesting feature apparent from Tables V and VI is that for the same number of canes in the sample, there is a reduction in the Standard Error if the shape of the sample chosen be a long and narrow one. A few discrepancies here and there, however, do not upset the general finding. The length of the patch from which the required number of canes is to be counted should be much greater than its width. A similar finding was obtained by Panse [1941] while dealing with the efficiency of different plot sizes. According to him the Standard Error decreased considerably if the plot was long and narrow.

TABLE V

No. of canes	No. of replications	Shape of the sample	Standard deviation	Standard error	Co-efficient of variation	Standard error of coefficient of variation
50	400	1 : 1	14·622	2·068	26·064	0·9215
100	200	1 : 2	11·945	1·1945	21·292	1·0646
100	200	2 : 1	11·796	1·1796	21·027	1·0513
Average			11·870	1·187	21·160	
200	100	1 : 4	10·324	0·7300	18·403	1·3014
200	100	1 : 1	9·800	0·6930	17·468	1·2139
Average			10·062	0·7115	17·935	
250	80	5 : 1	9·970	0·6306	17·789	1·4063
250	80	1 : 5	8·293	0·5245	14·782	1·1686
Avreage			9·132	0·5776	16·286	
400	50	1 : 8	9·219	0·4610	16·433	1·6433
400	50	1 : 2	8·808	0·4404	15·686	1·5686
Average			9·013	0·4507	16·060	
500	40	1 : 2·5	8·930	0·3994	15·919	1·7798
500	40	2·5 : 1	8·595	0·3844	15·321	1·7467
500	40	1 : 10	6·538	0·2924	11·654	1·3029
Average			8·21	0·3587	14·298	
800	25	1 : 4	8·078	0·2856	14·399	2·0363
1000	20	5 : 4	8·675	0·2743	15·454	2·4439
1000	20	1 : 5	7·937	0·2510	14·148	2·2372
1000	20	1 : 20	5·836	0·1845	10·403	1·6450
Average			7·483	0·2366	13·335	
1250	16	1 : 1	5·844	0·1653	10·417	1·8415
2000	10	1 : 1·6	7·682	0·1718	13·684	3·0598
2000	10	1 : 10	5·439	0·1216	9·695	2·1679
Average			6·560	0·1467	11·689	
2500	8	1 : 2	5·989	0·1198	10·675	2·6687
5000	4	1 : 4	5·807	0·0821	10·351	3·6600

The sample of 500 canes having different shapes, viz. 1 : 2·5 and 1 : 10 as the nature of the sample were studied. Both the Tables V and VI indicate a fall in the values of the Standard Deviation, Standard Error and the Coefficient of Variation in the sample with 1 : 10 as its shape. Thus we arrive at the conclusion that 500 canes with 1 : 10 as the ratio in the breadth and the length of the patch from which this number of canes is counted is probably the best among the samples considered in the present investigations.

It is clear from Tables V and VI that samples having 500, 800 and 1000 canes differ very little in the values of the Standard Deviation, Standard Error and the Coefficient of Variation. A further study about the number of replications of such samples will also help to determine the requisite size of the sample. The number of samples required to give Standard Error of 5 per cent was calculated by dividing the Coefficient of Variation of the sample by $\sqrt{n}$.

TABLE VI

No. of canes	No. of replications	Shape of the sample	Standard deviation	Standard error	Co-efficient of variation	Standard error of coefficient of variation
50	400	1 : 1	12·349	1·746	22·0107	0·7782
100	200	1 : 2	8·809	0·8809	15·7023	0·7851
100	200	2 : 1	9·889	0·9889	17·6112	0·8806
Average			9·349	0·9349	16·6568	
200	100	1 : 4	6·805	0·4812	12·1354	0·8581
200	100	1 : 1	6·697	0·4736	11·9376	0·8441
Average			6·751	0·4774	12·0365	
250	80	5 : 1	7·307	0·4621	13·0251	1·0298
250	80	1 : 5	5·775	0·3653	10·2940	0·8139
Average			6·541	0·4137	11·6596	
400	50	1 : 8	4·772	0·1236	8·5062	0·8506
400	50	1 : 2	5·283	0·2642	9·4171	0·9417
Average			5·028	0·2514	8·9616	
500	40	1 : 2·5	4·555	0·2037	8·1196	0·9070
500	40	2·5 : 1	4·461	0·1995	7·9518	0·8898
500	40	1 : 10	4·227	0·1890	7·5240	0·8412
Average			4·414	0·1974	7·8651	
800	25	1 : 4	3·857	0·1364	6·8752	0·9723
1000	20	5 : 4	4·211	0·1332	7·5062	1·1853
1000	20	1 : 5	3·845	0·1216	6·8538	1·0837
1000	20	1 : 20	4·211	0·1332	7·5062	1·1853
Average			4·890	0·1293	7·2877	
1250	16	1 : 1	3·240	0·0916	5·7575	1·0178
2000	10	1 : 1·6	3·920	0·0877	6·9875	1·5625
2000	10	1 : 10	3·930	0·0878	7·0053	1·5664
Average			3·925	0·0878	6·9964	
2500	8	1 : 2	3·142	0·0628	5·6007	1·4002
5000	4	1 : 4	2·900	0·0410	5·1693	1·8276

TABLE VII

Number of samples	Without removing the effect of columns and rows						After removing the effect of columns and rows					
	Size of the sample						Size of the sample					
	500 canes		800 canes	1000 canes			500 canes		800 canes	1000 canes		
	Shape of the sample		Shape of the sample	Shape of the sample			Shape of the sample		Shape of the sample	Shape of the sample		
	1 : 2·5	1 : 10	1 : 4	1 : 1·25	1 : 5	1 : 20	1 : 25	1 : 10	1 : 4	1 : 1·25	1 : 5	1 : 20
1	15·919	11·654	14·399	15·454	14·148	10·403	8·119	7·524	6·875	7·5062	6·853	7·5
2	11·37	8·241	10·285	11·04	10·000	7·359	5·792	5·302	4·904	5·290	4·888	5·29
3	9·36	6·729	8·470	9·09	8·140	6·000	4·700	4·360	4·000	4·350	4·000	4·35
4	7·959	5·827	7·195	7·727	7·074	5·201	4·059	3·762		3·753		3·753
5	7·23	5·212	6·545	7·02	6·335	4·673						
6	6·459	4·758	5·856	6·31	5·781	4·246						
7	6·071		5·333	5·85	5·351							
8	5·685		5·106	5·51	5·017							
9	5·306		4·799	5·151	4·716							
10												

For determining the number of replications of samples of three different sizes, viz. 500, 800 and 1000 canes, required to give accurate estimates, the data are arranged in Table VII.

Considering the variance without removing the effect of rows and columns, we find that if the size of the sample is to be 500 canes with shape 1 : 10 and 1 : 2·5 we would be required to take 6 and 9 replications respectively so as to make the sampling efficient enough to reduce the Standard Error to 5 per cent or lower. This further stresses the desirability of having a long and narrow patch for taking observations to record infestation percentage. Seven replications of the sample having 800 canes are needed and for a sample of 1000 canes, the number of replications required are 9, 8 and 5 for 5 : 4, 1 : 5 and 1 : 20 shapes respectively.

A similar study of the data after removing the effect of columns and rows reveals that 3 replications of the sample having 500 canes with shape 1 : 2·5 and 2 replications of the same sample with shape 1 : 10 reduce the Standard Error to about 5 per cent : two replications of the sample having 800 canes and shape 1 : 4 are necessary and for 1000 canes sample 2 to 3 replications are required.

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SUMMARY

Sugarcane top-borer (*Scirpophaga nivella* F.) is a serious pest of sugarcane in the Punjab and it is often required to accurately determine the extent of its infestation. The present paper presents the results of an Ento-Statistical investigation conducted with a view to find out the most suitable, effieient, and convenient size of the sample which would yield reliable information about the incidence of this pest. The infestation percentage figures in samples of various sizes and shapes have been examined statistically and the limits of accuracy have been determined. For ordinary routine work, a sample consisting of 500 canes has been shown to give quite accurate results. There appears to be very little advantage in precision if the size of the sample is increased beyond 500 canes. The precision is increased by taking long and narrow strips of the sugarcane crop for counting purposes. In special cases when greater efficiency is needed 3 to 6 replications of the sample consisting of 500 canes from strips with 1 : 10 and 1 : 2·5 as the ratios in their breadth and length respectively should be taken.

REFERENCES

Myers, J. G. (1932). *International Sugar J.* **34**, 376-9

Panse, V. G. (1941). Studies in the technique of field experiments, V. Size and shape of blocks and arrangement of plots in cotton trials. *Indian J. agric. Sci.*, **11**, 850-65

A PRELIMINARY INVESTIGATION INTO THE INFLUENCE OF THE FUNDAMENTAL DIMENSIONS OF A PLOUGH ON DRAW-BAR-PULL, DEPTH AND RESISTANCE PER UNIT AREA

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(With two text-figures)

Introduction

The fundamental dimensions of an Indian plough are the length of the wedge (L), the angle between the beam and the wedge (θ_p), the face angle of the wedge (θ) (i.e. the angle between the two edges of the wedge) and the weight (W). These are independent of one another and can be adjusted in any manner according to requirements, subject to some limitations.

It can be seen from the following discussions that the angle between the beam and the wedge cannot be more than a particular value if the plough is to work smoothly. In the case of Indian ploughs the line of draw-bar-pull either coincides or makes a small angle with the beam. The functions of a plough are to cut and to crush the soil. It does cutting while penetrating the soil during which it will have to overcome a certain amount of resisting force which is represented by F in Fig. 1. It

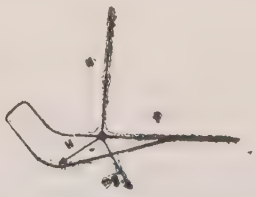

Fig. 1

crushes the soil during its forward push by the animals when it has to overcome a certain amount of complex forces in the soil, the resultant of which will act nearly at about right angles to the wedge and is represented by N in Fig. 1. The force which is equivalent to frictional resistance against the motion of the plough is represented by H. The directions of these forces are indicated by arrows. Assuming the cutting and crushing forces to be equal, in view of the gravitational force of the weihgt acting on the plough, the actual force in Fig. 2. contributed by the draw-bar-pull in the direction of the wedge is less than F and hence the resultant (R) of this force and N will be inclined at an angle greater than 45° to the wedge. Compared with the other forces, H is small and the resultant of R and H which is represented by P in Fig. 2 will be inclined at about 45° to the

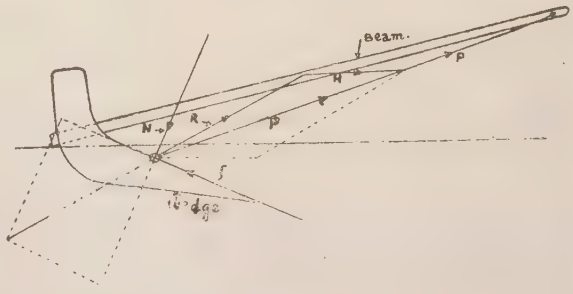

Fig. 2

wedge. This P is the draw-bar-pull and is recorded by dynamometer. We have already mentioned that the line of draw-bar-pull either coincides or makes a small angle with the beam. Hence the inclination of the beam with the wedge will be between 40° and 50° for smooth working. The weight of the plough should be adjusted in accordance with the strength required, but should not be increased unnecessarily in which case the average bullocks will find difficult to pull it. Similarly the face angle also has certain limitations. If the face angle is large, the resisting force against the penetration of the wedge is also large and the ploughing will not be deep enough under ordinary ploughing conditions. On the other hand, if the face angle is very small, the wedge will be too narrow and will penetrate to a greater depth which sometimes is not required. Besides this, the side pressure will be more and the draw-bar-pull will be large.

No work seems to have been done either in India or elsewhere regarding the influence of the fundamental dimensions of plough on draw-bar-pull, depth of ploughing and resistance per square inch of furrow opened. The available literature on the subject has been summarized below.

Contrary to the general opinion, Arthur Young [Keen, 1931] found that the draw-bar-pull was not affected by the weight of the plough to any appreciable extent. The main resistance was that offered by cohesion of the soil and could only be kept to a minimum by the proper design of

mould-board. Hadley [Keen, 1931] showed that the draught varied with the depth of ploughing and the gross draw-bar-pull appeared to be largely due to the frictional resistance between the sole and land side of the plough and not due to the mould-board. He confirmed Young's observation regarding the effect of weight of plough on the draw-bar-pull. White [1918] working at Illinios, America, attempted to work out the mathematical equations of surfaces of mould-boards of the most important historical ploughs. He also gave methods to generate plough bottoms for various soil conditions. Davies' at Rothamsted, studied the effect of the depth and width of the furrows on draw-bar-pull and found a linear relation existing between them. Keen and Haines [1925], at Rothamsted, showed that the relation between moisture and the draw-bar-pull is hyperbolic. Nichols [1931 ; 1932] at Albama, U. S. A., found a definite relation existing between friction, shear, resistance to the compression and the Atterberg consistency constants. In further dynamic studies of the soil, he established a relationship between friction and hardness of the metal of the plough share (or wedge) and colloidal contents of the soil. Godbole [1913] at Poona, in designing a new Deccan plough used the weight of the plough and the weight of the soil over the plough wedge in calculating the frictional resistance.

Attempts have been made in this paper to study the relation between the fundamental dimensions described above and draw-bar-pull, depth of the furrow and the resistance per square inch of furrow. Mathematical equations showing the relationship between the various factors have been obtained. It may be mentioned that in place of the plough angle, the angle between the horizontal and the wedge at the time of ploughing has been used in these equations, in order to eliminate the effect of the length of the beam and the height of bullocks. These equations enable us to calculate the draw-bar-pull, the depth and the resistance for ploughs of any dimensions for the same conditions for which the relation has been established. These calculated values can be used to judge the *relative merits* of ploughs of different dimensions. Therefore these equations are likely to be of more practical value than the equations connecting draw-bar-pull with depth and width of furrow as obtained by Davies. In the former case the approximate values of draw-bar-pull, depth and resistance can be known without actual ploughing, while in the other case the draw-bar-pull can be known after ploughing only.

Experiment

Seventeen Indian ploughs collected from different parts of India were worked in the same field with the same pair of bullocks by the same ploughman. The field used for this purpose was plot 3 E in Main Block of the Farm area, the soil of which is sandy loam. The plot was ploughed and left fallow for two months before the experiment. The draw-bar-pull was recorded by a self-recording dynamometer similar to that used by Keen [1931], excepting that there was no arrangement for the automatic motion of the paper and for pin pricks to indicate any point of the furrow on the chart. The draw-bar-pull charts were obtained in this case by rotating the paper drum with hand by a man who was moving along with the plough with the dynamometer hanging from his neck. Therefore, the relation between the motions of paper and plough and the draw-bar-pull at any point of the furrow could not be found from the chart. The average draw-bar-pull for the different furrows was calculated by computing the area included between the curve and the base line by means of a planimeter and dividing the area by the length of base line and multiplying the quotient with the constant of the dynamometer. The depth and width of the furrow were measured with the help of a wooden divider. This was placed inside the furrow with its arms touching the sides of furrow and a wooden scale was placed across the furrow touching the divider. Then with a second scale the distance between the arms of divider at the top of furrow and the height of the horizontal scale from the bottom of furrows were measured. The former is the width and the latter is the depth of the furrow. The resistance was calculated by using the draw-bar-pull and the area of the cross-section of the furrow opened. Table I summarizes the results of this experiment.

Results and discussions

The partial regression coefficient between the draw-bar-pull and the depth and width of furrows, the weight of the plough, the time taken to open 100 ft. furrow, the moisture and the angle which the wedge makes with the horizontal were not significant in any of the cases excepting depth. This shows that draw-bar-pull is likely to depend more on the depth of ploughing than on any other factor for the conditions of this experiment ; but the depth, as will be seen from the investigations that follow, will depend on the weight of plough, the length of the wedge, the face angle of the wedge and the angle which the wedge makes with the horizontal at the time of ploughing.

The correlation coefficient between the draw-bar-pull and the depth was 0·9259 and the regression equation connecting the draw-bar-pull with depth and its analysis of variance are given below :

TABLE I*

Name of the plough	Weight of the plough in lb.	Length of the wedge in inches	Angle which wedge makes with horizontal	θ		Moisture per cent	Time to open 100 ft. furrow in seconds	Width of furrow in inches	Depth of the furrow		D. B. P. in lb.	Resistance per sqr. in.	
				Observed value	Cultivated value				Observed value	Calculated value		Observed value	Calculated value
1. Country plough Indore	56·9	30	21·2	10·2	25·8	8·28	43	9·66	10·66	9·01	416·0	8·08	6·33
2. Country plough Dohad	28·7	35	21·2	8·2	34·1	7·66	24	9·33	9·33	6·33	360·0	8·28	2·91
3. Country plough Coimbatore	37·4	34	18·2	12·4	32·0	8·64	35	11·00	9·00	7·02	358·0	6·82	3·74
4. Country plough Baroda	50·7	36	18·0	13·3	27·6	8·34	33	11·50	8·00	8·45	305·6	6·63	5·57
5. Local plough Karnal	51·6	28	23·0	31·7	27·4	8·40	29	12·00	8·20	8·48	295·0	6·00	5·46
6. Country plough Bareilly No. 2	25·0	32	23·1	6·8	35·4	9·69	42	8·66	7·16	5·91	226·0	7·30	2·42
7. Plough Dacca Farm	23·9	34	24·9	14·0	36·6	9·45	28	9·33	7·00	5·50	182·0	5·57	1·96
8. Country plough Aligarh	29·2	29	20·0	16·8	35·3	9·18	34	9·83	7·66	5·95	166·2	4·41	2·47
9. Wooden plough Berhampore	36·4	31	14·2	17·0	34·0	9·33	28	10·00	7·66	6·38	134·4	3·51	2·97
10. *Desi* plough Gorakhpore No. 3	23·5	27	23·0	23·2	36·7	9·50	30	9·00	6·00	5·48	134·0	4·51	1·94
11. Country plough Bankura	31·0	28	18·8	39·0	35·1	9·81	27	12·00	6·33	6·00	127·7	3·36	2·53
12. Country plough Rangpur	20·0	24	19·1	19·2	39·3	9·56	25	9·00	5·67	4·64	126·5	4·96	1·05
13. Wooden plough Gorakhpore	22·6	28	23·0	21·2	36·8	9·15	30	9·66	6·33	5·44	118·0	3·86	1·89
14. *Desi* plough Gorakhpore	22·0	28	19·0	21·2	38·0	9·25	31	10·66	7·00	5·07	108·6	3·58	1·54
15. Local plough Chotanagpur Daltonganj	30·2	31	16·9	24·0	35·3	8·78	25	10·83	6·00	5·94	85·1	2·62	2·44
16. L. P. Chotanagpur Purelia	25·1	29	23·2	20·0	35·8	8·36	28	9·83	6·20	5·77	65·9	2·16	2·25
17. Udayagiri Orissa	17·2	22	21·5	18·6	40·0	8·59	23	10·33	6·00	4·42	82·3	2·65	0·81

* The help rendered by Mr A. K. Kaul, Engineering Assistant, Imperial Agricultural Research Institute, in maintaining the dynamometer is gratefully acknowledged

$Y = 74{\cdot}90\,d - 358{\cdot}07$; where Y stands for draw-bar-pull in lb. and d for depth of the furrow in inches.

In this equation when $d = 0$, the draw-bar-pull is —358·07 lb. The draw-bar-pull is zero when $d = 4\frac{3}{4}$ in. This was so because the plot had been ploughed once two months before the experiment and it appeared to be difficult to measure the draw-bar-pull at depths less than the above value in this field.

Analysis of variance for Y *expressed in terms of* d

Variance due to	D. F.	S. S.	M. S. S.	Ratio of variation
Linear regression	1	166081·1	166081·1	90·5
Residual error	15	27665·9	1844·4	

The above analysis shows that the draw-bar-pull depends mainly on the depth of the furrow opened. This measurement of the depth can be known only by actual trials. But if it is possible, to establish some relationship between the depth (d) and the weight (W), length (L), face angle of the wedge (θ) and the angle which the wedge makes with the horizontal at the time of ploughing (Φ), the depth can be calculated approximately when the values of W, L, θ and Φ are known. It may be emphasized here that the depth so calculated will hold good only for the particular soil on which the experiment was conducted. The partial regression equation between d, W, L, θ and Φ and its analysis of variance are as follows:

$$d = 3{\cdot}489 + 0{\cdot}0829\,W + 0{\cdot}0437\,L - 0{\cdot}0684\,\theta + 0{\cdot}0595\,\Phi$$

Analysis of variance for d *expressed in terms of* W, L, θ, *and* Φ

Variation due to	D. F.	S. S.	M. S. S.	Ratio of variance
Regression	4	21·949	5·487	8·6
Residual	12	7·657	0·683	

The above table shows that the partial regression equation can be used to express d in terms of the independent measurements of a plough subject to a variation of about 11 per cent. It also shows that depth d increases as W, L and Φ increase but decreases as θ increases.

Since d is dependent on W, L, θ and Φ and Y is dependent on d, by combining the above two equations we have the following equation in which Y is expressed in terms of W, L, θ and Φ :—

$$Y = 6{\cdot}21\,W + 3{\cdot}27\,L + 4{\cdot}6\Phi - 5{\cdot}12\theta - 96{\cdot}74.$$

This equation enables us to calculate the draw-bar-pull directly with the knowledge of W, L, θ and Φ.

So far we have discussed the relationship between the fundamental dimensions of plough and draw-bar-pull and depth of ploughing. But to judge a plough completely, we must know the draw-bar-pull, the depth and the resistance (R) per unit area of the cross-section ploughed. Therefore we shall now examine the relation, if any, between resistance per square inch and other factors. The correlation coefficient between R and d and R and θ were 0·791 and — 0·600 respectively. As the above correlations are not so high as that between draw-bar-pull and depth, a second degree equation involving R, θ and d was fitted to the data. The equation and its analysis of variance are given below :

$$R = 24{\cdot}21 - 1{\cdot}063\,\theta + 0{\cdot}014\,\theta^2 + 0{\cdot}0715\,\theta\,d - 3{\cdot}010d + 0{\cdot}1616d^2.$$

Analysis of variance for R *expressed in terms of* θ *and* d

Variance due to	D. F.	S. S.	M. S. S.	Ratio of variance
Second degree equation	5	50·99	10·20	11·1
Residual error	11	10·16	0·92	

The analysis of variance shows that R can be estimated subject to a variation of about 19 per cent, if θ and d are known. If d is replaced in terms of W, L, θ and Φ we obtain an equation involving R, W, L, θ and Φ and this equation enables us to discuss how the resistance varies with the changes in W, L, θ and Φ. Using the partial regression equation between d, W, L, θ and Φ ; R and d we get

$$R = 15{\cdot}68 - 0{\cdot}1561\,W - 0{\cdot}0822\,L - 0{\cdot}6848\,\theta - 0{\cdot}1120\,\Phi + 0{\cdot}0012\,W\,L + 0{\cdot}0041\,W\,\theta + 0{\cdot}0016\,W\,\Phi + 0{\cdot}0021\,L\,\theta + 0{\cdot}0008\,L\,\Phi + 0{\cdot}0030\,\theta\,\Phi + 0{\cdot}0011\,W^2 + 0{\cdot}0003\,L^2 + 0{\cdot}0063\,\theta^2 + 0{\cdot}0006\,\Phi^2.$$

The coefficients of W^2, L^2, θ^2 and Φ^2 are all positive. Hence it follows that R will have a minimum value for certain values of W, L, θ and Φ. The equations which give the minimum values are :

$$\frac{dR}{dW} = -0{\cdot}156 + 0{\cdot}0012\,L + 0{\cdot}0041\,\theta + 0{\cdot}0016\,\Phi + 0{\cdot}0022\,W.$$

$$\frac{dR}{dL} = -0{\cdot}082 + 0{\cdot}0012\,W + 0{\cdot}0021\theta + 0{\cdot}0008\Phi + 0{\cdot}0006L$$

$$\frac{dR}{d\theta} = -0{\cdot}685 + 0{\cdot}0041W + 0{\cdot}0021\,L + 0{\cdot}0030\Phi + 0{\cdot}0126\theta$$

$$\frac{dR}{d\Phi} = -0{\cdot}112 + 0{\cdot}0016\,W + 0{\cdot}0008\,L + 0{\cdot}0030\theta + 0{\cdot}0012\Phi$$

Equating the above equations to zero and solving them we get the values of W, L, θ and Φ when the resistance is minimum. For this minimum value of resistance W, L and Φ are negative. Hence it is not possible to have a plough having minimum resistance under all conditions. For given value of W, L and θ, which are governed by the nature of soil, depth of ploughing and the power available, it is possible to adjust θ so that the resistance is minimum. θ appears to be the only measurement that can be adjusted to give the minimum resistance. From the minimum resistance point of view, the value of θ has been obtained for the ploughs of this experiment. Taking these values of θ, the probable depth and resistance for the respective ploughs have been calculated. The columns 6, 11 and 14 of Table I give the observed and the calculated values of R, d, θ for minimum resistance. From these value of θ, R and d it appears that Karnal, Baroda Bankura, Chotanagpur, Daltonganj and Purelia (items 4, 5, 11, 15 and 16) have their face angle (θ) within the limits of minimum resistance and can be considered to be good designs subject to the limitations of depth.

Summary

Equations showing the relation between the fundamental dimensions of a plough (weight W, length of wedge L, the face angle of the wedge θ, and the angle which the wedge makes with the horizontal at the time of ploughing Φ) and draw-bar-pull, depth and resistance per unit area of cross-section ploughed have been obtained for the soil on which the ploughs were tested. These equations appear to be of considerable value for judging the relative merits of ploughs. Further work is in progress.

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References

Davies, W. M. (1924). A preliminary investigation into the draft of the plough. *J. agric. Sci.* **14**, 370-406

Godbole, S. S. (1913). Improvements of the indigenous plough of Western India. *Dept. Agri., Bombay, Bull.* **57**

Keen, B. A. (1935). *Physical Properties of Soil.* Longmans Green & Co.

Nichols, M. L. (1930). Agricultural engineering investigations at the Alabama Station. *Albama Sta. Rept.* 9-11

——————(1931). The dynamic properties of soil, *Agric. Engineering*, **12**. 259-64 & 321-4 (Abstract *Expt. Sta. Rec. U. S. Dept. Agri.*, **66**, 1932, 378-9)

White, ... A. (1918). A study of the plow bottom and its action upon the furrow slice. *J. agric. Res.* **12**, 149-82

TEN PER CENT PROBABILITY OF Z AND THE VARIANCE RATIO

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Fisher and Yates [1938] have given tables of z and the variance ratio for four levels of prohibility, viz., 0·2, 0·05, 0·01 and 0·001. Values of z for $P=0{\cdot}1$ and the corresponding values of the variance ratio are presented here in Tables I and II. These will fill up an important gap between the probability levels 0·2 and 0·01.

The present tables were primarily prepared to make available to plant breeders a somewhat less stringent test of significance in replicated progeny row trials than the conventional 5 per cent level. When continuous selection is made either from crosses or from natural un-

selected material, the initially present genetic variability is gradually reduced to a level at which differences between progenies are frequently shown to be non-significant when the usual test of significance at the 5 per cent level is applied in the analysis of variance. This, however, does not necessarily mean that all genetic variance is exhausted and the material rendered unsuitable for further selection. Actually, with the reduction of genetic variability and persistence of environmental variability, detection of small genetic differences becomes more difficult, particularly in characters such as yield, where the environmental variation is considerable. Due to the limited amount of seed produced by single plants, there is also a natural limitation to the efficiency of the layout. On the other hand, it is desirable to make further selection where possible, even though it be with a lower degree of confidence in the genetic superiority of the selected progenies, rather than discard the whole material. The reason is that once a start is made with variable material, the chances of securing maximum progress are greater by accumulating small improvements resulting from continued selection in this material, than by replacing it by fresh material except when such fresh material possesses a higher initial variability. Under these conditions, a z test at ten per cent level of significance and a corresponding t test are likely to prove useful in exploring the possibility of making further selection.

The use of ten per cent values of z was suggested by Hutchinson and Panse [1937] in another and a slightly different situation in plant breeding. They recommended that nucleus stock of a strain that has been bred and distributed should be maintained by running a small progeny row trial in place of the present method of growing a number of typical, vigorous, productive plants to provide the nucleus. In analysing the data of the progeny row trial, a table of z for $P=0{\cdot}1$ will be of great value, as a plant breeder will be ready to discard a progeny if he knows that the odds are ten to one that it is lower yielding than the standard.

The present tables are based on the tables of Incomplete Beta Function for $P=0{\cdot}1$, prepared by Miss Catherine Thompson [1941]. Fisher [1935] has given the distribution of z as,

$$df=\frac{\left(\frac{n_1+n_2-2}{2}\right)!}{\left(\frac{n_1-2}{2}\right)!\left(\frac{n_2-2}{2}\right)!}q^{\frac{1}{2}(n_1-2)}(1-q)^{\frac{1}{2}(n_2-2)}dq$$

Where n_1 and n_2 are the degrees of freedom of the two variances to be compared and $q=\frac{n_1 e^{2z}}{n_1 e^{2z}+n_2}$.

The distribution is related to Beta-distributions through x, the argument of the Incomplete Beta Function, being equal to $\frac{n_2}{n_1 e^{2z}+n_2}$, i.e. to $1-q$. The values of x are tabulated by Thompson. Conversion from x to z and to the variance ratio was a simple matter.

Values of z and the variance ratio are given in Tables I and II for all values of n_1 up to 10 and of n_2 up to 30. Beyond these points, interpolation can be made, where necessary, by using $\frac{1}{n}$ as the variable by the method given by Fisher [1936], since the values of n_1 beyond 10 and of n_2 beyond 30, given in the tables, are in harmonic progression. For larger values of n_1 and n_2 that is when n_1 is greater than 40 and n_2 greater than 60, it is desirable to calculate the values of z from Fisher's asymptotic formula as modified by Cochran [1940]. For $P=0.1$, the modified formula is:

$$Z=\frac{1{\cdot}2816}{\sqrt{h-0{\cdot}77}}-0{\cdot}6071\left(\frac{1}{n_1}-\frac{1}{n_2}\right)$$

where $\frac{2}{h}=\frac{1}{n_1}+\frac{1}{n_2}$

In his introduction to Miss Thompson's tables, Pearson had stated that tables of the variance ratio for different levels of probability including 0·1 had been prepared and it was hoped to include them in a new edition of Tables for Statisticians and Biometricians. Since then these tables calculated by Miss Thompson have been published in Biometrica (Vol. XXXIII, pages 78-79, 1943); but the present tables which were independently computed by us are being published here, with the full concurrence of the editor of Biometrica, to make them readily available to plant breeders and other research workers in India.

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REFERENCES

Cochran, W. G. (1940). *Ann. Math. Statist.* **11**, 93
Fisher, R. A. (1935). *Econometrica*, **3**, 353
———(1936). *Statistical Methods for Research Workers. 6th edition.* Oliver and Boyd, London
———, and Yates, F. (1938). *Statistical Tables for Biological, Agricultural and Medical Research.* Oliver and Boyd, London
Hutchinson, J.B., and Panse, V.G. (1937). Studies in Plant Breeding Technique, II. The design of field tests of plant breeding material. *Indian J. agric. Sci.* **7**, 531
Thompson, C. M. (1941). *Biometrica* **32**, 151

TABLE I

Distribution of z —10 per cent points

n_2 \ n_1	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∝
1	1·8427	1·9510	1·9907	2·0112	2·0236	2·0320	2·0380	2·0424	2·0460	2·0488	2·0530	2·0572	2·0614	2·0636	2·0657	2·0678	2·0699	2·0720	2·0742
2	1·0716	1·0986	1·1075	1·1119	1·1146	1·1164	1·1176	1·1186	1·1193	1·1199	1·1208	1·1216	1·1225	1·1230	1·1234	1·1239	1·1243	1·1247	1·1252
3	0·8558	0·8489	0·8423	0·8378	0·8347	0·8324	0·8306	0·8293	0·8282	0·8272	0·8258	0·8244	0·8228	0·8220	0·8213	0·8204	0·8196	0·8188	0·8179
4	0·7570	0·7321	0·7164	0·7064	0·6994	0·6944	0·6905	0·6874	0·6850	0·6830	0·6799	0·6765	0·6733	0·6716	0·6698	0·6680	0·6661	0·6642	0·6623
5	0·7006	0·6648	0·6432	0·6293	0·6196	0·6125	0·6071	0·6029	0·5994	0·5966	0·5921	0·5875	0·5826	0·5801	0·5775	0·5748	0·5722	0·5694	0·5665
6	0·6643	0·6211	0·5952	0·5786	0·5669	0·5583	0·5512	0·5465	0·5422	0·5387	0·5332	0·5273	0·5212	0·5181	0·5148	0·5114	0·5080	0·5044	0·5007
7	0·6390	0·5905	0·5615	0·5427	0·5294	0·5197	0·5121	0·5061	0·5012	0·4971	0·4907	0·4839	0·4767	0·4730	0·4691	0·4651	0·4610	0·4567	0·4523
8	0·6203	0·5678	0·5364	0·5160	0·5015	0·4907	0·4824	0·4757	0·4702	0·4657	0·4585	0·4509	0·4428	0·4386	0·4342	0·4296	0·4249	0·4200	0·4148
9	0·6060	0·5504	0·5171	0·4953	0·4798	0·4682	0·4592	0·4520	0·4461	0·4411	0·4333	0·4250	0·4161	0·4114	0·4065	0·4014	0·3962	0·3906	0·3849
10	0·5947	0·5365	0·5017	0·4788	0·4624	0·4502	0·4406	0·4330	0·4266	0·4213	0·4130	0·4040	0·3944	0·3893	0·3840	0·3784	0·3727	0·3666	0·3602
11	0·5855	0·5253	0·4892	0·4653	0·4483	0·4355	0·4254	0·4173	0·4107	0·4051	0·3962	0·3867	0·3764	0·3710	0·3653	0·3593	0·3530	0·3465	0·3396
12	0·5779	0·5160	0·4788	0·4541	0·4365	0·4232	0·4127	0·4043	0·3973	0·3914	0·3821	0·3721	0·3613	0·3555	0·3494	0·3431	0·3364	0·3294	0·3219
13	0·5715	0·5082	0·4701	0·4447	0·4265	0·4128	0·4019	0·3932	0·3859	0·3798	0·3702	0·3597	0·3483	0·3422	0·3359	0·3291	0·3221	0·3145	0·3066
14	0·5660	0·5015	0·4626	0·4366	0·4180	0·4038	0·3927	0·3836	0·3762	0·3699	0·3598	0·3490	0·3371	0·3307	0·3241	0·3170	0·3096	0·3016	0·2931
15	0·5613	0·4957	0·4561	0·4296	0·4106	0·3961	0·3846	0·3754	0·3677	0·3612	0·3508	0·3396	0·3273	0·3207	0·3137	0·3063	0·2985	0·2902	0·2812
16	0·5572	0·4907	0·4504	0·4235	0·4041	0·3893	0·3776	0·3681	0·3602	0·3536	0·3429	0·3313	0·3186	0·3118	0·3046	0·2969	0·2888	0·2800	0·2706
17	0·5536	0·4863	0·4455	0·4181	0·3984	0·3833	0·3714	0·3617	0·3536	0·3468	0·3359	0·3240	0·3109	0·3039	0·2964	0·2884	0·2800	0·2709	0·2611
18	0·5504	0·4823	0·4410	0·4134	0·3933	0·3780	0·3658	0·3560	0·3477	0·3408	0·3296	0·3174	0·3040	0·2968	0·2890	0·2809	0·2721	0·2626	0·2524
19	0·5476	0·4788	0·4371	0·4091	0·3887	0·3732	0·3609	0·3508	0·3424	0·3354	0·3240	0·3116	0·2978	0·2903	0·2824	0·2740	0·2649	0·2552	0·2445
20	0·5451	0·4757	0·4336	0·4052	0·3846	0·3689	0·3564	0·3462	0·3377	0·3305	0·3189	0·3062	0·2922	0·2846	0·2764	0·2677	0·2584	0·2483	0·2373
21	0·5427	0·4728	0·4304	0·4017	0·3809	0·3650	0·3524	0·3420	0·3334	0·3261	0·3143	0·3014	0·2870	0·2792	0·2710	0·2620	0·2525	0·2421	0·2306
22	0·5407	0·4703	0·4275	0·3986	0·3776	0·3615	0·3487	0·3382	0·3295	0·3220	0·3101	0·2970	0·2824	0·2744	0·2659	0·2568	0·2470	0·2363	0·2245
23	0·5388	0·4679	0·4248	0·3957	0·3745	0·3582	0·3453	0·3347	0·3259	0·3184	0·3062	0·2929	0·2781	0·2700	0·2613	0·2520	0·2419	0·2310	0·2188
24	0·5370	0·4658	0·4224	0·3931	0·3717	0·3553	0·3422	0·3315	0·3226	0·3150	0·3027	0·2892	0·2741	0·2658	0·2570	0·2475	0·2373	0·2260	0·2135
25	0·5354	0·4638	0·4201	0·3906	0·3691	0·3525	0·3394	0·3286	0·3195	0·3118	0·2994	0·2857	0·2704	0·2621	0·2531	0·2434	0·2329	0·2214	0·2086
26	0·5339	0·4619	0·4181	0·3884	0·3667	0·3500	0·3367	0·3258	0·3167	0·3089	0·2964	0·2825	0·2670	0·2585	0·2494	0·2396	0·2289	0·2171	0·2039
27	0·5326	0·4603	0·4162	0·3863	0·3645	0·3477	0·3343	0·3233	0·3141	0·3063	0·2936	0·2796	0·2639	0·2552	0·2460	0·2360	0·2251	0·2131	0·1996
28	0·5313	0·4587	0·4144	0·3844	0·3624	0·3455	0·3320	0·3210	0·3117	0·3038	0·2910	0·2768	0·2609	0·2522	0·2428	0·2327	0·2216	0·2093	0·1955
29	0·5301	0·4572	0·4128	0·3826	0·3605	0·3435	0·3299	0·3188	0·3094	0·3015	0·2886	0·2742	0·2582	0·2493	0·2398	0·2295	0·2182	0·2057	0·1916
30	0·5290	0·4559	0·4112	0·3809	0·3587	0·3416	0·3280	0·3167	0·3073	0·2993	0·2862	0·2718	0·2556	0·2467	0·2370	0·2266	0·2151	0·2024	0·1880
40	0·5211	0·4461	0·4001	0·3688	0·3457	0·3279	0·3136	0·3018	0·2919	0·2834	0·2696	0·2541	0·2366	0·2268	0·2162	0·2046	0·1916	0·1770	0·1599
60	0·5132	0·4363	0·3890	0·3567	0·3328	0·3142	0·2993	0·2868	0·2764	0·2674	0·2526	0·2360	0·2170	0·2063	0·1945	0·1814	0·1665	0·1491	0·1279
120	0·5055	0·4266	0·3780	0·3446	0·3198	0·3005	0·2848	0·2718	0·2606	0·2511	0·2354	0·2175	0·1967	0·1848	0·1716	0·1565	0·1389	0·1174	0·0880
∝	0·4977	0·4170	0·3671	0·3326	0·3069	0·2866	0·2702	0·2565	0·2448	0·2346	0·2178	0·1984	0·1755	0·1622	0·1470	0·1293	0·1075	0·0779	0·0000

TABLE 11

Variance ratio—10 per cent points of e^{2z}

n_2 \ n_1	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	39·86	49·50	53·59	55·83	57·24	58·20	58·91	59·44	59·86	60·20	60·70	61·22	61·74	62·00	62·26	62·53	62·79	63·06	63·33
2	8·53	9·00	9·16	9·24	9·29	9·32	9·35	9·37	9·38	9·39	9·41	9·42	9·44	9·45	9·46	9·47	9·47	9·48	9·49
3	5·54	5·46	5·39	5·34	5·31	5·28	5·27	5·25	5·24	5·23	5·22	5·20	5·18	5·18	5·17	5·16	5·15	5·14	5·13
4	4·54	4·32	4·19	4·11	4·05	4·01	3·98	3·96	3·94	3·92	3·90	3·87	3·84	3·83	3·82	3·80	3·79	3·78	3·76
5	4·06	3·78	3·62	3·52	3·45	3·40	3·37	3·34	3·32	3·30	3·27	3·24	3·21	3·19	3·17	3·16	3·14	3·12	3·10
6	3·78	3·46	3·29	3·18	3·11	3·05	3·01	2·98	2·96	2·94	2·90	2·87	2·84	2·82	2·80	2·78	2·76	2·74	2·72
7	3·59	3·26	3·07	2·96	2·88	2·83	2·78	2·75	2·72	2·70	2·67	2·63	2·60	2·58	2·56	2·54	2·51	2·49	2·47
8	3·46	3·11	2·92	2·81	2·73	2·67	2·62	2·59	2·56	2·54	2·50	2·46	2·42	2·40	2·38	2·36	2·34	2·32	2·29
9	3·36	3·01	2·81	2·69	2·61	2·55	2·50	2·47	2·44	2·42	2·38	2·34	2·30	2·28	2·26	2·23	2·21	2·18	2·16
10	3·28	2·92	2·73	2·60	2·52	2·46	2·41	2·38	2·35	2·32	2·28	2·24	2·20	2·18	2·16	2·13	2·11	2·08	2·06
11	3·22	2·86	2·66	2·54	2·45	2·39	2·34	2·30	2·27	2·25	2·21	2·17	2·12	2·10	2·08	2·05	2·03	2·00	1·97
12	3·18	2·81	2·61	2·48	2·39	2·33	2·28	2·24	2·21	2·19	2·15	2·10	2·06	2·04	2·01	1·99	1·96	1·93	1·90
13	3·14	2·76	2·56	2·43	2·35	2·28	2·23	2·20	2·16	2·14	2·10	2·05	2·01	1·98	1·96	1·93	1·90	1·88	1·85
14	3·10	2·73	2·52	2·40	2·31	2·24	2·19	2·15	2·12	2·10	2·05	2·01	1·96	1·94	1·91	1·89	1·86	1·83	1·80
15	3·07	2·70	2·49	2·36	2·27	2·21	2·16	2·12	2·09	2·06	2·02	1·97	1·92	1·90	1·87	1·84	1·82	1·79	1·76
16	3·05	2·67	2·46	2·33	2·24	2·18	2·13	2·09	2·06	2·03	1·98	1·94	1·89	1·87	1·84	1·81	1·78	1·75	1·72
17	3·03	2·64	2·44	2·31	2·22	2·15	2·10	2·06	2·03	2·00	1·96	1·91	1·86	1·84	1·81	1·78	1·75	1·72	1·69
18	3·01	2·62	2·42	2·29	2·20	2·13	2·08	2·04	2·00	1·98	1·93	1·89	1·84	1·81	1·78	1·75	1·72	1·69	1·66
19	2·99	2·61	2·40	2·27	2·18	2·11	2·06	2·02	1·98	1·96	1·91	1·86	1·81	1·79	1·76	1·73	1·70	1·67	1·63
20	2·98	2·59	2·38	2·25	2·16	2·09	2·04	2·00	1·96	1·94	1·89	1·84	1·79	1·77	1·74	1·71	1·68	1·64	1·61
21	2·96	2·58	2·36	2·23	2·14	2·08	2·02	1·98	1·95	1·92	1·88	1·83	1·78	1·75	1·72	1·69	1·66	1·62	1·59
22	2·95	2·56	2·35	2·22	2·13	2·06	2·01	1·97	1·93	1·90	1·86	1·81	1·76	1·73	1·70	1·67	1·64	1·60	1·57
23	2·94	2·55	2·34	2·21	2·12	2·05	2·00	1·95	1·92	1·89	1·84	1·80	1·74	1·72	1·69	1·66	1·62	1·59	1·55
24	2·93	2·54	2·33	2·20	2·10	2·04	1·98	1·94	1·91	1·88	1·83	1·78	1·73	1·70	1·67	1·64	1·61	1·57	1·53
25	2·92	2·53	2·32	2·18	2·09	2·02	1·97	1·93	1·90	1·87	1·82	1·77	1·72	1·69	1·66	1·63	1·59	1·56	1·52
26	2·91	2·52	2·31	2·17	2·08	2·01	1·96	1·92	1·88	1·86	1·81	1·76	1·71	1·68	1·65	1·62	1·58	1·54	1·50
27	2·90	2·51	2·30	2·17	2·07	2·00	1·95	1·91	1·87	1·84	1·80	1·75	1·70	1·67	1·64	1·60	1·57	1·53	1·49
28	2·89	2·50	2·29	2·16	2·06	2·00	1·94	1·90	1·86	1·84	1·79	1·74	1·68	1·66	1·62	1·59	1·56	1·52	1·48
29	2·89	2·50	2·28	2·15	2·06	1·99	1·94	1·89	1·86	1·83	1·78	1·73	1·68	1·65	1·62	1·58	1·55	1·51	1·47
30	2·88	2·49	2·28	2·14	2·05	1·98	1·93	1·88	1·85	1·82	1·77	1·72	1·67	1·64	1·61	1·57	1·54	1·50	1·46
40	2·84	2·44	2·23	2·09	2·00	1·93	1·87	1·83	1·79	1·76	1·72	1·66	1·60	1·57	1·54	1·51	1·47	1·42	1·38
60	2·79	2·39	2·18	2·04	1·95	1·88	1·82	1·78	1·74	1·71	1·66	1·60	1·54	1·51	1·48	1·44	1·40	1·35	1·29
120	2·75	2·35	2·13	1·99	1·90	1·82	1·77	1·72	1·68	1·65	1·60	1·55	1·48	1·45	1·41	1·37	1·32	1·26	1·19
∞	2·71	2·30	2·08	1·94	1·85	1·77	1·72	1·67	1·63	1·60	1·55	1·49	1·42	1·38	1·34	1·30	1·24	1·17	1·00

STATISTICAL NOTES FOR AGRICULTURAL WORKERS

No. 26. INFLUENCE OF DATES OF PLANTING AND SPACINGS ON SOME WINTER VARIETIES OF RICE

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(With three text-figures)

The increase in the production of rice rests in general with the evolution of high-yielding strains suitable for different localities, and if suitable cultural methods are adopted for growing these strains the yield could further be enhanced. The study of the effect of different cultural treatments on the rice plant is therefore a very important problem for all rice growing tracts.

With a view to having a precise idea of the effects of the cultural factors, such as, time of planting, age of seedling, spacing, number of seedlings per hole, etc. on the yield of some selected strains of rice of different ripening habits under the conditions obtaining at the Dacca Farm, a series of cultural experiments were laid out in 1936-37 and repeated for a number of years successively. The present paper deals with the results of one of the experiments which was conducted in five successive years, from 1936-37 to 1940-41. It involved three factors, viz. date of planting, strain of rice and spacing.

Material and method

The experiment comprised of the following three sets of factors :

(1) *Three strains of winter rice* :
- (*i*) Latisail—with early maturing habit.
- (*ii*) Indrasail—with medium maturing habit.
- (*iii*) Tilakkachari—with late maturing habit.

(2) *Six dates of planting* : (*i*) 1 July, (*ii*) 16 July, (*iii*) 1 August, (*iv*) 16 August, (*v*) 1 September, (*vi*) 16 September.

(3) *Three spacings* : (*i*) Six inches, (*ii*) Nine inches, (*iii*) Twelve inches.

The factors gave altogether $6 \times 3 \times 3$ or 54 different treatments. Each treatment was replicated three times giving a total of 162 unit plots, each measuring 9 ft. $\times$ 20 ft. or about 1/240th acre in area.

Of the three factors included in this experiment, the first alone, namely, varieties, is qualitative. In the case of this factor our object is only to compare the three varieties among themselves and decide which is the best variety and so on. But our object in the case of the second factor, namely, date of planting, is not merely to make a comparison between the six selected dates ; for, these dates are not likely to be more important than any other six dates separated by fortnightly intervals belonging to the range of time July to September. Our problem may be either (*i*) to predict the yield of the crop if the planting had been done on any date falling within the range of time covered from 1 July to 16 September, or (*ii*) to know whether the yield reaches a maximum on some date within this period. In the second case we will be proceeding on the hypothesis that the yield will vary regularly as in a smooth curve having a single maximum at a date lying within the range of time covered in the experiment. We may therefore say that we are trying to fix the optimal date of the yield curve which we have previous reason to believe will lie somewhere between 1 July and 16 September. In experiments of this nature, careful planning is necessary, in the choice of the range and the number of points of time selected for experimental study. After doing the experiment for two or more years, it will be possible to arrive at a first approximation of the optimal date, and if the experiment is modified by shortening the range of the points we will be able to fix the optimal date with greater precision, thus affording a gradual close-up study of this date. On the other hand, if the object of the experiment is merely to supply a sort of yield table for various dates of planting, irrespective of whether an optimal date exists or not, it will be necessary to select a large number of dates over as wide a range of time as is allowable under practical considerations.

What have been said above regarding the dates of planting applies with equal force to the third factor, namely *spacing*. We can consider the three spacings selected, namely 6 in., 9 in., 12 in. as only convenient points to study the yield curve for a continuous range of spacings. Since three ordinates of the curve have been selected for study we are allowing for detection of any curvature in the curve which gives it a single maximum. If this optimal spacing lies between 6 in. and 12 in. it could be determined with some reliability. But if the optimal spacing falls outside the range, the three points selected will lie in one limb of the curve

almost along a straight line leading us to a possibly wrong conclusion that there is no optimal spacing at all. The interpretation of yield curve for this factor is complicated by the fact that for shorter spacings, proportionately more plants will be growing in the plot, resulting in greater total yield, unless the yield per plant is reduced as a result of closer spacing. Two different questions may be asked, namely, (*i*) what is the optimal spacing and hence the number of plants when a certain specified area is available for cultivation, (*ii*) what is the optimal spacing and hence the area of plot required when a certain specified number of plants is available for cultivation. Generally, (*i*) is of more frequent occurrence than (*ii*), but the answer to both questions will be simultaneously available from our experiment.

Layout

The experiment was laid out in a long stretch of land of almost uniform fertility, in three blocks of equal size, each containing one complete set of all the treatments. The blocks were separated from one another by bunds for the facility of agricultural operations and to maintain in all the three blocks approximately the same depth of water during the growth of the crop.

To facilitate cultural operations, the plots of the same date of planting were, first of all, laid out in long rows (or strips) and the positions occupied by six such rows corresponding to the different dates of planting, within each block, were determined at random. Likewise and for the same reason the plots under the three different strains of rice were distributed separately into three compact strips running across the rows and their respective positions within each block were fixed up at random. Ultimately the three different spacings were assigned at random within each combination of date of planting and strain of rice. The layout plan of the experiment is shown in Fig. 1, from which it will be seen that we have adopted a combination of strip and split plot arrangements.

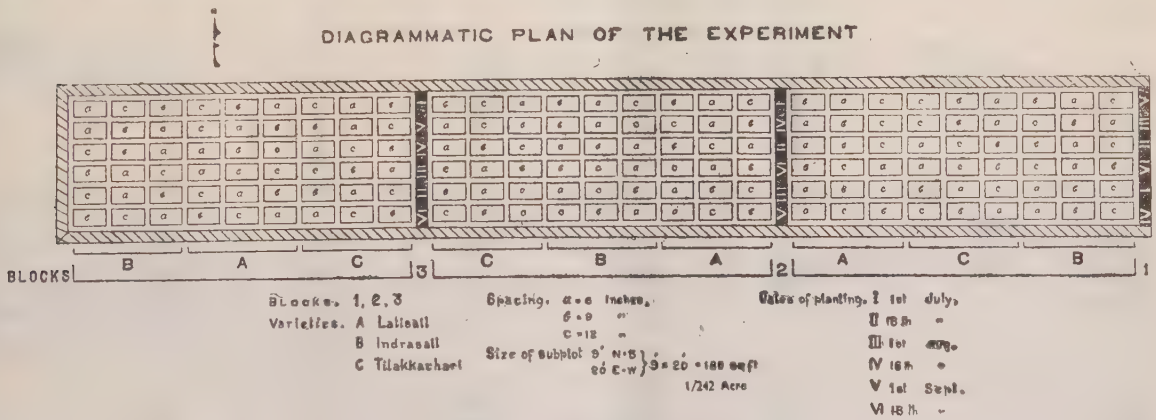

Fig. 1. Layout plan

The dates of planting and the strains of rice were the whole plot or strip treatments while spacing was the sub-plot treatment each with its appropriate error. For the weights of grain and straw the whole produce from each unit plot was gathered.

Rainfall

The five-day totals of rainfall in the Dacca Farm during the season for each of the five years, and the total number of rainy days during each five-day period, are shown in Table I. The normal rainfall for each month is also given to help study of seasonal variation in yield.

Analysis of data and discussion of results

The analysis of variance of the yields of grain and straw of all the five years are shown in Tables IIA and IIB. To economize space only the values of variances have been given. There are four different error variances associated with soil variation between plots of the four different sizes occurring within each block. The various main effects and interactions have been so arranged that variance due to each of them can be tested for significance against its appropriate Error Variance, which appears just below it. The error variances have been numbered (I), (II), (III), (IV) for identification.

From Table IIA, we find that the only effects on yield of grain which were significant in every year are variations between dates of planting, and between spacings and the interaction between dates of planting and spacings. All of them are highly significant at 1 per cent level. In 1937-38 alone some of the interactions between strains of rice, date of planting and spacing came out significant, but being an isolated result we need not attach any significance to it.

TABLE I

Five-day totals of rainfall in inches at Dacca Farm

Period	1936-37		1937-38		1938-39		1939-40		1940-41		Normal rainfall for the month
	Rainfall	No. of rainy days	Rainfall	No. of rainy days	Rainfall	No. of rainy days	Rainfall	No. of rainy days	Rainfall	No. of rainy days	
March											
1—5	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0·69	2	
6—10	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0·04	1	
11—15	Nil	Nil	Nil	Nil	0·40	1	Nil	Nil	0·10	1	
16—20	0·13	1	Nil	Nil	Nil	Nil	0·32	1	0·85	2	
21—25	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0·71	2	
26—31	1·78	2	Nil	Nil	Nil	Nil	0·98	2	0·62	2	
Total	1·91	3	Nil	Nil	0·40	1	1·30	3	3·01	10	1·05
April											
1—5	0·25	1	Nil	Nil	0·06	1	Nil	Nil	Nil	Nil	
6—10	1·36	2	Nil	Nil	0·81	1	0·16	2	Nil	Nil	
11—15	Nil	Nil	Nil	Nil	0·40	1	Nil	Nil	Nil	Nil	
16—20	1·17	2	1·12	1	0·34	1	Nil	Nil	0·56	1	
21—25	Nil	Nil	0·27	2	1·71	3	0·08	1	0·17	1	
26—30	Nil	Nil	0·23	2	1·99	3	0·04	1	Nil	Nil	
Total	2·78	5	1·62	5	5·31	10	0·28	4	0·73	2	3·22
May											
1—5	0·48	2	Nil	Nil	4·08	4	0·66	1	0·17	1	
6—10	2·34	2	2·96	4	0·45	4	2·42	4	1·30	1	
11—15	0·57	3	Nil	Nil	2·37	2	Nil	Nil	0·55	2	
16—20	1·54	2	5·41	4	1·75	3	0·99	2	0·67	1	
21—25	0·10	1	3·52	3	2·70	2	1·27	1	4·72	5	
26—31	5·78	4	2·34	5	8·51	5	0·49	1	1·19	1	
Total	10·81	14	14·23	16	19·86	20	5·83	9	8·60	11	10·09
June											
1—5	3·94	5	1·10	4	0·11	3	1·30	3	Nil	Nil	
6—10	1·59	3	0·29	3	0·25	3	0·97	3	1·91	2	
11—15	0·85	5	0·58	4	2·96	5	0·97	4	4·46	5	
16—20	1·10	3	4·60	4	2·02	4	0·53	5	3·32	3	
21—25	1·47	3	2·01	3	1·64	3	3·71	5	Nil	Nil	
26—30	1·72	3	0·46	3	4·71	3	2·34	5	0·23	3	
Total	10·67	22	9·04	21	11·69	21	9·82	25	9·92	13	11·56
July											
1—5	1·53	3	0·40	4	0·15	1	0·99	2	1·80	5	
6—10	2·59	4	4·05	3	3·13	4	0·46	5	0·62	3	
11—15	4·86	5	1·40	5	1·11	5	8·76	5	0·05	1	
16—20	1·49	5	0·97	4	0·97	4	0·74	5	2·78	4	
21—25	1·09	2	0·52	3	1·19	3	1·00	4	0·44	3	
26—31	3·96	6	1·91	5	6·13	5	18·97	6	0·74	4	
Total	15·52	25	9·25	24	12·68	22	30·92	27	6·43	20	13·51
August											
1—5	4·15	5	0·78	4	4·60	4	13·09	5	3·22	4	
6—10	2·87	5	7·01	5	8·09	4	1·42	4	4·77	4	
11—15	1·01	1	6·32	5	1·27	4	1·87	4	0·62	4	
16—20	3·10	5	0·13	3	2·05	3	1·49	4	0·06	1	
21—25	1·71	3	2·07	4	1·52	4	0·54	4	0·34	3	
26—31	1·72	4	2·69	5	0·75	4	0·70	3	2·49	4	
Total	14·56	23	19·00	26	18·28	23	19·11	24	11·50	20	14·03
September											
1—5	0·59	3	0·75	3	3·26	5	1·01	4	4·79	3	
6—10	1·60	4	1·63	3	1·05	2	2·17	4	2·70	5	
11—15	4·34	4	0·48	4	2·06	3	1·67	5	1·13	3	
16—20	1·66	2	0·47	2	6·96	5	1·95	2	0·09	2	
21—25	1·38	1	1·85	4	0·07	1	2·34	3	6·09	5	
26—30	Nil	Nil	3·04	3	Nil	Nil	1·07	2	0·12	2	
Total	9·57	14	8·22	19	13·40	16	10·21	20	14·92	20	9·90
October											
1—5	1·85	3	0·20	3	Nil	Nil	4·04	4	Nil	Nil	
6—10	0·11	1	1·11	2	0·02	1	5·71	2	Nil	Nil	
11—15	1·29	2	0·51	2	0·71	2	0·08	1	Nil	Nil	
16—20	0·18	2	Nil	Nil	1·51	3	0·07	1	Nil	Nil	
21—25	Nil	Nil	Nil	Nil	1·21	2	3·76	3	3·47	3	
26—31	Nil	Nil	Nil	Nil	Nil	Nil	0·21	2	Nil	Nil	
Total	3·43	8	1·82	7	3·45	8	13·87	13	3·47	3	4·86
November											
1—5	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
6—10	Nil	Nil	Nil	Nil	0·20	1	Nil	Nil	Nil	Nil	
11—15	0·08	1	Nil	Nil	0·70	2	Nil	Nil	Nil	Nil	
16—20	0·72	2	Nil	Nil	Nil	Nil	Nil	Nil	0·14	1	
21—25	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
26—30	Nil	Nil	1·18	2	Nil	Nil	0·01	1	Nil	Nil	
Total	0·80	3	1·18	2	0·90	3	0·01	1	0·14	1	1·06

TABLE I—*contd.*

Period	1936-37		1937-38		1938-39		1939-40		1940-41		Normal rainfall for the month
	Rain-fall	No. of rainy days	Rain-fall	No. of rainy days	Rain-fall	No. of rainy days	Rain-fall	No. of rainy days	Rain-fall	No. of rainy days	
December											
1—5	Nil	Nil	0·05	1	Nil	Nil	Nil	Nil	Nil	Nil	
6—10	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
11—15	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
16—20	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
21—25	0·02	1	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
26—31	0·04	1	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
Total	0·06	2	0·05	1	Nil	Nil	Nil	Nil	Nil	Nil	0·21
January											
1—5	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
6—10	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
11—15	Nil	Nil	0·39	1	Nil	Nil	Nil	Nil	Nil	Nil	
16—20	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
21—25	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0·14	1	
26—31	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0·59	1	
Total	Nil	Nil	0·39	1	Nil	Nil	Nil	Nil	0·73	2	0·12
February											
1—5	Nil	Nil	0·05	1	Nil	Nil	Nil	Nil	Nil	Nil	
6—10	0·09	1	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
11—15	1·85	3	1·06	2	0·45	1	0·31	1	Nil	Nil	
16—20	Nil	Nil	0·11	1	Nil	Nil	Nil	Nil	2·95	1	
21—25	0·74	2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
26—28	Nil	Nil	Nil	Nil	Nil	Nil	1·36	2	Nil	Nil	
**29	...	...	...	...	...	...	0·47**	1	...	...	
Total	2·68	6	1·22	4	0·45	1	2·14	4	2·95	1	1·32

** In case of Leap-year only

In case of yield of straw also, Table IIB points to similar conclusions as in the case of yield of grain for the main effects of dates and spacings. But their interaction is not significant except in one year. An additional feature is that the variations due to strains of rice is significant at 5 per cent level in three out of the five years. The interaction : Dates of Planting × Strains of rice, is significant at 1 per cent level in two years, whereas the three-factor interaction is significant at 5 per cent level in only one year.

TABLE IIA

Analysis of variance (yield of grain in tolas)

	Degrees of freedom	Variance				
		1936-37	1937-38	1938-39	1939-40	1940-41
Block	2	81482·34	72258·67	10676·08	78413·57	81443·19
Strain of rice	2	92740·63	210426·89	19677·00	62027·46	42192·12
Error (I)	4	53151·38	38492·11	17937·65	9905·51	25239·21
Date of planting	5	446908·51**	617315·36**	362845·34**	329354·27**	525175·37**
Error (II)	10	13999·35	24433·10	21490·15	18774·13	21195·87
Date of planting × Strain of rice	10	13029·22	17287·81*	6964·41	13787·02	12703·41
Error (III)	20	6279·25	6778·20	11341·17	5804·58	12308·17
Spacing	2	35955·28**	135574·52**	84746·45**	90535·80**	78208·03**
Spacing × Date of planting	10	14234·69**	15000·42**	18798·30**	18686·35**	20356·74**
Spacing × Strain of rice	4	4350·11	1570·07	5666·36	3856·04	6484·79
Spacing × Strain of rice × Date of planting.	20	3941·37	15178·19**	5400·99	4164·99	309·77
Error (IV)	72	3589·86	6982·82	6359·57	3202·01	5448·02

N. B.—Items marked with one and two asterisks are both significant, the former at the level of 5 per cent probability and the latter at the level of 1 per cent probability

The determination of straw yield was not done as accurately as in the case of grain. After threshing, both grain and straw were left in the sun and their weights were taken when dry. In the former case the drying was done for quite a long time with such care that more or less a constant weight was reached, while in the case of the latter so much care could not be taken. There was therefore no guarantee that the extent of drying of straw was comparable in each season. The standard error per plot for each of the different plot sizes has been calculated as a percentage of the mean yield for both grain and straw in each of the five years. This is given in Table III. It will be seen that the standard error was greater for straw than for grain. Also while the values of S. E. per cent for the various years are more or less steady for grain, there are wide fluctuations in the case of straw.

TABLE II B

Analysis of variance (yield of straw in tolas)

	Degrees of freedom	Variance				
		1936-37	1937-38	1938-39	1939-40	1940-41
Block	2	383285·34	1161858·25	186941·82	837551·08	430433·91
Strain of rice	2	1361896·45*	787239·43	1458553·84	975029·79*	1751933·56*
Error (I)	4	132180·48	483906·39	334731·64	91058·95	104037·55
Date of planting	5	3159798·02**	5418854·55**	4120980·15**	2558610·52**	4462671·27**
Error (II)	10	46059·97	532764·04	347809·60	218019·97	294997·59
Date of planting × Strain of rice	10	101429·97**	92033·62	73283·86	16700·90	178403·57**
Error (III)	20	20639·78	81066·52	82291·08	16231·73	35193·14
Spacing	2	950824·23**	2371421·80**	637523·30**	634277·94**	698418·74**
Spacing × Date of planting	10	13377·75	74885·15	27116·64	10506·27	64789·65*
Spacing × Strain of rice	4	22535·34	46467·73	37471·46	18840·66	3767·60
Spacing × Strain of rice × Date of planting	20	26492·75*	2103·43	34199·78	17363·72	23099·62
Error (IV)	72	15857·56	51618·28	61076·69	12959·88	15868·47

N. B.—Items marked with one and two asterisks are both significant, the former at the level of 5 per cent probability and the latter at the level of 1 per cent probability

TABLE III

Standard error per cent per plot

Year	Error I		Error II		Error III		Error IV	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1936-37	52·14	55·04	26·75	32·40	17·92	21·75	13·55	19·07
1937-38	37·97	59·97	30·24	62·93	15·93	24·55	16·17	19·59
1938-39	30·28	70·27	33·15	71·63	24·08	34·85	18·03	30·01
1939-40	24·42	63·86	33·62	98·79	18·70	26·96	13·79	24·08
1940-41	40·53	48·65	37·14	81·89	28·32	28·29	19·08	19·00

Since only the two factors, date of planting and spacing indicated significant effects every year on the yield of grain and straw the mean yield in tolas per plot for each combination of these two factors are given in Tables IVA and IVB. The standard errors for comparing the means of dates of planting and of spacings are separately given.

We note that the yield of grain is greater for the second date of planting than for the first date; and for the third and later dates, the yield registers a progressive fall. But yield of straw is greatest for the earliest date of planting. Similarly out of the three spacings, 6 in. gives the best yield for both grain and straw; the wider spacings of 9 in. and 12 in. giving progressively lower yield. This result is consistent over all the five years, although the five seasons give widely varying mean yields, namely, 442, 517, 442, 407 and 392 for grain and

661, 1160, 823, 673 and 663 for straw. To test whether these variations between years and their interactions with other factors are significant a combined analysis of variance of the five years data can be done, provided the error variances are not significantly different. This latter point was investigated by an approximate Chi-square (χ^2) test introduced by Yates and Cochran [1938]. The values of χ^2 are given in Table V. We find that none of the values of Chi-square is significant in the case of grain, which means the error variances are comparable and a pooled analysis of variance admissible. In the case of straw the pooled analysis is not valid and was not therefore undertaken.

TABLE IV A

Dates of planting × Spacings (mean yield of grain in tolas per plot)

Spacings	Dates of planting						Mean	Standard Error (Spacings)
	July 1 (I)	July 16 (II)	Aug. 1 (III)	Aug. 16 (IV)	Sept. 1 (V)	Sept. 16 (VI)		
1936-37								
(*a*) 6 in.	504·11	583·22	519·89	485·89	433·44	292·78	469·89	8·17
(*b*) 9 in.	557·78	556·89	499·00	441·11	347·22	226·89	438·15	
(*c*) 12 in.	568·44	591·00	470·33	414·22	292·78	175·89	418·78	
Mean	543·44	577·07	496·41	447·07	357·82	231·85	442·27	
Standard Error (dates of planting)	22·77							
1937-38								
(*a*) 6 in.	639·11	683·11	680·67	567·78	495·56	328·67	565·81	11·37
(*b*) 9 in.	655·11	662·00	619·56	503·78	452·89	219·78	518·85	
(*c*) 12 in.	636·89	603·56	566·00	396·67	325·33	265·56	465·67	
Mean	643·70	649·56	622·07	489·41	424·52	271·33	516·78	
Standard Error (dates of planting)	30·08							
1938-39								
(*a*) 6 in.	516·67	581·11	521·11	477·78	470·00	308·89	479·26	10·85
(*b*) 9 in.	498·89	593·33	462·22	482·22	394·44	251·11	447·04	
(*c*) 12 in.	576·67	504·44	451·11	410·00	303·33	157·22	400·46	
Mean	530·74	559·63	478·15	456·67	389·26	239·07	442·25	
Standard Error (dates of planting)	28·21							
1939-40								
(*a*) 6 in.	472·11	518·33	489·22	468·44	420·67	290·67	443·24	7·71
(*b*) 9 in.	512·00	529·56	153·11	431·00	335·56	237·67	416·48	
(*c*) 12 in.	545·56	491·11	400·11	338·22	248·56	153·46	362·83	
Mean	509·89	513·00	447·48	412·52	334·93	227·26	407·50	
Standard Error (dates of planting)	26·37							
1940-41								
(*a*) 6 in.	487·89	580·11	514·44	396·78	401·78	200·11	430·19	10·04
(*b*) 9 in.	493·00	540·56	428·78	400·89	325·11	161·67	391·67	
(*c*) 12 in.	511·56	507·11	418·22	339·78	232·22	115·56	354·07	
Mean	497·48	542·59	453·82	379·15	319·70	159·11	391·98	
Standard Error (dates of planting)	28·02							

Table VI gives the pooled analysis of variance for grain yield. The appropriate error variance to test the effect of years is the item blocks × years with 8 d. f. We find that when so tested the effect of years is highly significant. There are only four other effects, namely, main effect of dates, main effect of spacings, main effect of strains and the interaction between date and spacing which are all highly significant. It is very important to note that there is no interaction between years and any of the factors, strains, dates or spacings. We have therefore got a definite picture of the influences of date of planting and of spacing which should be applicable to a wide range of seasonal conditions obtainable at Dacca if the five years under consideration give a fair sample of seasons.

TABLE IV B

Dates of planting × Spacings (mean yield of straw in tolas per plot)

Spacings	Dates of planting							
	July 1 (I)	July 16 (II)	Aug. 1 (III)	Aug. 16 (IV)	Sept. 1 (V)	Sept. 16 (VI)	Mean	Standard Error (Spacings)
1936-37								
(*a*) 6 in.	1321·11	1132·22	860·00	711·11	487·78	352·78	810·83	17·14
(*b*) 9 in.	1066·67	904·44	671·11	476·11	299·44	252·22	611·67	
(*c*) 12 in.	997·78	821·11	689·44	421·11	248·89	177·78	559·35	
Mean	1128·52	952·59	740·19	536·11	345·37	260·93	660·62	
Standard Error (dates of planting)	41·32							
1937-38								
(*a*) 6 in.	1868·44	1693·33	1630·22	1463·11	794·67	752·00	1366·96	30·92
(*b*) 9 in.	1859·00	1336·22	1336·89	1160·00	739·56	562·67	1164·63	
(*c*) 12 in.	1595·56	1088·44	1115·56	890·67	529·78	467·56	947·93	
Mean	1772·15	1372·67	1360·89	1171·26	688·00	594·07	1159·84	
Standard Error (dates of planting)	140·48							
1938-39								
(*a*) 6 in.	1462·22	1232·22	886·67	911·11	607·78	482·22	930·19	33·64
(*b*) 9 in.	1388·33	1167·78	714·44	755·56	507·78	427·78	826·94	
(*c*) 12 in.	1437·78	1035·56	567·78	588·89	403·33	266·67	712·96	
Mean	1421·67	1145·19	722·96	751·85	506·30	392·22	823·36	
Standard Error (dates of planting)	113·50							
1939-40								
(*a*) 6 in.	1354·44	935·56	728·89	736·67	501·11	440·00	784·63	15·49
(*b*) 9 in.	1216·11	808·89	603·33	577·78	395·56	412·22	669·98	
(*c*) 12 in	1058·33	705·00	555·56	471·11	308·89	297·78	566·11	
Mean	1209·63	816·48	629·26	558·15	401·85	383·33	672·62	
Standard Error (dates of planting)	89·99							
1940-41								
(*a*) 6 in.	1380·00	1258·89	817·78	546·00	467·78	258·11	788·09	17·14
(*b*) 9 in.	1317·78	866·67	504·44	490·56	364·11	272·78	636·06	
(*c*) 12 in.	1200·00	835·56	553·56	395·33	264·89	142·78	565·35	
Mean	1299·26	987·04	625·26	477·30	365·59	224·56	663·17	
Standard Error (dates of planting)	104·53							

TABLE V

Values of χ^2 for Error Variances

Years	Error (I)		Error (II)		Error (III)		Error (IV)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1936-37	7·34	2·31	7·01	1·60	12·56	8·77	35·90	36·27
1937-38	5·28	8·45	12·22	18·50*	13·56	34·43*	69·83	118·07*
1938-39	2·48	5·84	10·75	12·08	22·68	34·95*	63·60	139·71*
1939-40	1·37	1·59	9·40	7·57	11·61	6·89	32·02	29·64
1940-41	3·49	1·80	10·61	10·24	24·62	14·95	54·48	36·30
Degrees of freedom	4		10		20		72	

*Significant at 5 per cent level

TABLE VI

Combined analysis of variance 5 years (yield of grain in tolas per plot)

	Degrees of freedom	Sum of squares	Variance
Blocks	2	511198·37	255599·19
Years	4	1501149·44	375287·36**
Blocks × Years	8	137349·33	17168·67
Strains of rice	2	391931·35	195965·67**
Strains of rice × Years	8	462196·87	57774·61
Error (I)	20	578903·52	28945·18
Dates of planting	5	11147209·17	2229441·83**
Dates of planting × Years	20	260785·11	13039·25
Error (II)	50	998925·95	19978·52
Strains of rice × Dates of planting	10	260161·27	26016·17
Strains of rice × Dates of planting × Years	40	377557·47	9438·93
Error (III)	100	850227·29	8502·27**
Spacings	2	809074·63	404537·31
Spacings × Strains of rice	4	31600·48	7900·22
Spacings × Dates of planting	10	578710·79	57871·08**
Spacings × Dates of planting × Strains of rice	20	175098·77	8754·94
Spacings × Years	8	40965·52	5120·69
Spacings × Strains of rice × Years	16	56205·67	3512·85
Spacings × Dates of planting × Years	40	192054·24	4801·36
Spacings × Dates of planting × Strains of rice × Years	80	504709·68	6308·87
Error(IV)	360	1841924·56	5116·46
Total	809	21707939·48	..

Since the main effect of strains of rice when averaged over the five seasons has come out significant, it is necessary to indicate which variety is best. Table VII gives the mean yield per plot of each variety in each of the five seasons.

TABLE VII

Mean yield of grain of the varieties (in tolas per plot)

Year	Strains of Rice			Critical difference at 5% level	Varieties which are significantly different
	A. Latisail	B. Indrasail	C. Tilakkachari		
1936-37	476·52	396·20	454·09	123·17	nil
1937-38	584·70	503 70	461·93	104·82	A > C
1938-39	425·93	463·24	437·59	68·23	nil
1939-40	446·57	390·15	385·83	53·16	A B ; A > C
1940-41	422·43	367·48	386·02	84 86	nil
All years	471·23	424·15	425·09	30·54	A > B ; A > C

The influence of date of planting and of spacing require a closer study. It is not enough if we decide in favour of one among the six dates chosen, or one among the three spacings. Both these factors are measurable and it is quite possible that the yield can be expressed as a mathematical function of the date or of spacing or of both. Once that mathematical function is determined with precision, the picture becomes objective and more complete than what the figures of Table IV could give. We can, in fact, pose the question, what date of planting between 1 July and 16 September is likely to give the maximum yield for grain. What spacing lying between 6 and 12 inches will likewise give the best yield ? Will this optimum date vary with the spacing or the optimum spacing vary with the date as is possible on account of the interaction between date and spacing ? All these questions have been answered in the further analysis taken up below.

Since there are six dates of planting, which though not exactly equidistant may be assumed to be so, we can plot graphs marking the dates along the axis of X and yield along the axis of Y. Four graphs can be obtained for each spacing and the mean of the 3 spacings as shown in Fig. 2. A fifth degree polynomial can be fitted at the most, but usually even a smaller degree curve gives quite an adequate fit. Another set of seven graphs where the spacings are marked along X-axis and yield along Y-axis can be prepared as in Fig. 3 for each date of planting and the mean over all dates. Here a second degree polynomial can be fitted. Whether a smaller degree, namely, straight line will be adequate can be tested by analysis of variance. Whenever the 3 curves obtained for yield-date relationships at different spacings are mutually parallel, or the six curves obtained for yield-spacing relationships at different dates of plantings are mutually parallel can also be tested by further

analysis of variance of the interaction: Date × Spacing. This detailed analysis has been done in Tables VIIIA and VIIIB for grain and straw respectively.

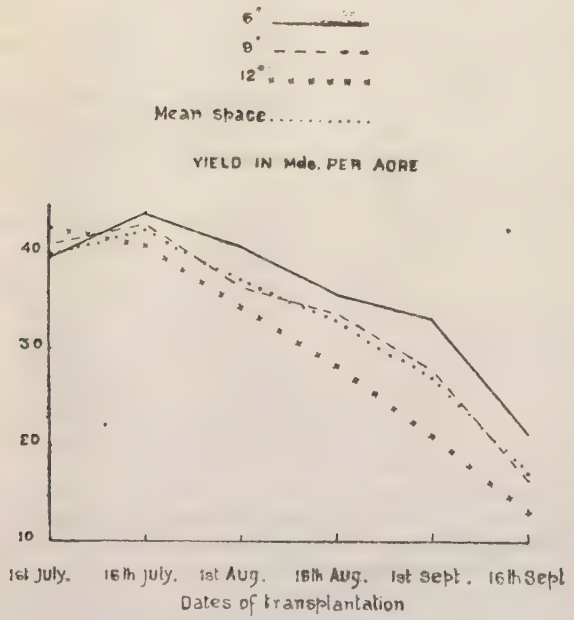

FIG. 2. Yield-date curves for different spacings

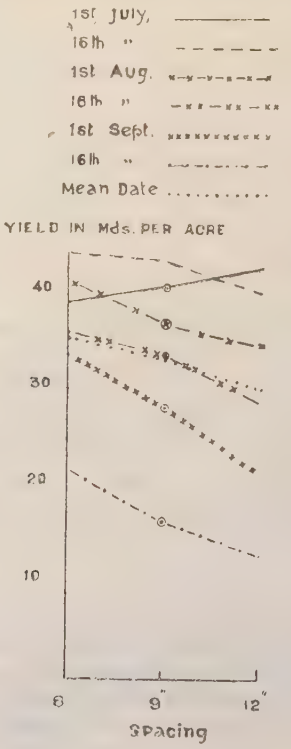

FIG. 3. Yield-spacing curves for different dates of transplanting

It will be seen that the yield-date relation can be adequately represented in the case of grain by a parabola of the form.

$$Y = a + bx + cx^2$$

where Y = yield, x = date of planting

In the case of straw the relation is adequately represented by a straight line. Similarly the yield-spacing relationship for both grain and straw are given by straight lines.

The detailed analysis of variance of the 10 d. f. for the interaction date × spacing of the grain yield reveals that the significance of this item is mainly due to 1 d. f. belonging to what we have called date (1st degree) × spacing (1st degree). Now the yield-date curve for any spacing 6 in., 9 in. or 12 in. is obtained by the formula

$$Y = A + B\left(x - \frac{7}{2}\right) + C\left\{\left(x - \frac{7}{2}\right)^2 - \frac{35}{12}\right\}$$
$$= a + bx + cx^2$$

The values of A, B, C obtained for each spacing is given in Table IX. We note that the three values of B increase in magnitude with increase in spacing and, if plotted, lie almost on a straight line. This is why we found the 1 d. f. for date (1st degree) × spacing (1st degree) significant. The values of C show a tendency of decreasing magnitude with increase of spacing but except in two years (1937-38 and 1940-41) this tendency is not significant as can be judged from the variance due to date (2nd degree) × spacing (1st degree).

The standard error of B and C have been calculated using the following formulae (see Appendix).

$$\text{S. E. of } B \text{ for each spacing} = \sqrt{\frac{2}{315}\left(\frac{\text{Error (II)} + 2\ \text{Error (IV)}}{3}\right)}$$

$$\text{S.E. of } C \text{ for each spacing} = \sqrt{\frac{1}{336}\left(\frac{\text{Error (II)} + 2\ \text{Error (IV)}}{3}\right)}$$

The appropriate test of significance of individual values of B or C is available in the Behrens and Fishers test for which Sukhatme [1938][9] has published tables. We have to enter this table with $n_1 = 10$, $n_2 = 72$ and $\tan^2\theta = \frac{\text{Error (II).}}{2\ \text{Error (IV)}}$ It can be immediately noted that at 12 in. spacing the values of C are not likely to be significant. The yield-date curve for 12 in. spacing must therefore be virtually taken as a straight line. Owing to the existence of a curvature in the yield-date curve within the range of dates studied, when the spacing

TABLE VIII A

Detailed analysis of variance—dates, Spacings, and Dates × Spacings (yield of grain in tolas)

	Degrees of freedom	Variance				
		1936-37	1937-38	1938-39	1939-40	1940-41
Dates—						
1st degree	1	1978736·36*	2748498·14*	1528888·90*	1515663·75*	2287334·66*
2nd degree	1	222659·08*	286976·25*	226300·28*	116616·04*	266868·78*
3rd degree	1	4537·53	8897·90	4850·01	108·75	4185·21
4th degree	1	19525·08	6876·19	41407·44	7224·30	67395·56
5th degree	1	9084·52	35328·34	12780·07	7158·50	92·66
Total	5	426908·51**	617315·36**	362845·34**	329354·27**	525175·37**
Error (II)	10	13999·35	24433·10	21490·15	18774·13	21195·87
Spacings—						
1st degree	1	70533·33*	270800·59*	167639·12*	174564·48*	156408·33*
2nd degree	1	1377·23	348·44	1853·78	6507·11	7·72
Total	2	35955·28**	135574·52**	84746·45**	90535·80**	78208·03**
Dates × Spacings—						
Dates (1st deg.) × Spacings (1st deg.)	1	121284·96*	25749·54*	113050·98*	142167·82*	40278·87*
Dates (2nd deg.) × Spacings (1st deg.)	1	6751·34	60901·59*	7986·52	2936·00	16264·35*
Dates (1st deg.) × Spacings (2nd deg.)	1	1124·83	12089·31	5931·28	10·79	2097·85
Dates (2nd deg.) × Spacings (2nd deg.)	1	1333·04	13412·70	4104·77	343·36	0·005
Dates (deviation from 2nd degree curve) × Spacings	6	1975·46	6308·50	9484·91	6900·93	24154·39
Total	10	14234·69**	15000·42**	18798·30**	18686·35**	20356·74**
Error (IV)	72	3589·86	6982·82	6359·57	3202·01	5448·02

* Significant at 5 per cent level

** Significant at 1 per cent level

is at 6 in. and 9 in. we are in a position to determine the best date of planting which is given by

$$p = -\frac{1}{2}\left(\frac{B}{C} - 7\right)$$

The values of p have been worked out in Table IX for 6 in. and 9 in. spacing. The standard error of p is calculated from the approximate formula

$$\text{S.E. of } p = \frac{B}{2C}\sqrt{\left(\frac{\text{S.E. of } B}{B}\right)^2 + \left(\frac{\text{S.E of } C}{C}\right)^2}$$

Fixing the values of p on the calendar we find that for 6 in. spacing, the best date of planting is invariably after the 2nd date used in the experiment, namely, 16 July. There is remarkable closeness in these optimum dates for various years. They are actually 21, 18, 21, 23, and 17 July in the respective years. The standard error of each estimated best date is about six days. For the 9 in. spacing the best date is between 1 July and 16 July except for one year, 1938-39 when it falls on 27 July. In the other years the dates are 1, 10, 2 and 8 July for 1936-37 to 1940-41. The standard error of these dates are higher than for the 6 in. spacing, and vary between 9 and 17 days. We cannot therefore make a very rigid location of the best date of planting. But the procedure followed in the statistical treatment of the data indicates lines of re-planning the experiment to achieve the purpose of fixing the best date.

In the case of yield of straw, Table IVB shows a downward linear trend with advancing date of planting and also with increase of spacing. There is no interaction between the two linear trends. We can only say that the earlier the date of planting the greater the yield of straw and that the wider the spacing between the plants the smaller the yield.

ACKNOWLEDGEMENT

In conclusion our thanks are due to Mr S. Raja Rao of the Calcutta Statistical Laboratory for checking some of the numerical work.

Table VIII B

Detailed analysis of variance—Dates, Spacings, and Dates × Spacings (yield of straw in tolas)

	Degrees of freedom	Variance				
		1936-37	1937-38	1938-39	1939-40	1940-41
Dates—						
1st degree	1	15620165·29**	25519611·60**	19089472·50**	11286805·83**	21040814·76**
2nd degree	1	95148·19	41229·67	741362·44	1098548·16	1107501·73
3rd degree	1	79691·85	17256·99	93746·71	179124·49	27936·30
4th degree	1	2235·45	1503127·12	35150·83	144309·56	104351·75
5th degree	1	1749·34	12793·50	632616·37	86256·84	32114·88
Total	5	3159798·02**	5418854·55**	4120980·15**	2558610·52**	4462671·27**
Error (II)	10	46059·97	532764·04	347809·60	218019·97	294997·59
Spacings—						
1st degree	1	1707559·07**	4740985·04**	1274008·33**	1267500·00**	1339562·81**
2nd degree	1	194089·20**	1858·57	1038·27	1074·38	59536·00
Total	2	950824·23**	2371421·80**	637523·30**	634277·94**	698418·74**
Dates × Spacings—						
Dates (1st deg.) × Spacings (1st deg.)	1	45240·08	52535·31	49406·43	40346·75	77534·49*
Dates (2nd deg.) × Spacings (1st deg.)	1	529·78	63259·69	16933·59	9·52	35071·11
Dates (1st deg.) × Spacings (2nd deg.)	1	15280·42	15288·47	16594·24	2986·69	78811·53*
Dates (2nd deg.) × Spacings (2nd deg.)	1	10664·03	103467·57	89688·91	21302·67	126096·79**
Dates (deviation from 2nd degree curve) × Spacings	6	10343·86	85716·74	24757·20	6736·17	55063·76
Total	10	13377·75	74885·15	27116·64	10506·27	64789·65*
Error (IV)	72	15857·56	51618·28	61076·69	12959·88	15868·47

* Significant at 5 per cent level ** Significant at 1 per cent level

Table IX

Calculation of best date of planting

Year	Spacing	A	B	S. E. of B	C	S. E. of C	a	b	$p = \frac{7}{2} - \frac{B}{C}$	S. E. of p	Best date of planting
1936-37	6 in.	469·89	—44·00	6·69	—18·85	4·58	448·06	87·92	2·33	0·33	21 July
	9 in.	438·15	—66·90		—13·24		548·87	25·76	0·97	0·92	1 July
	12 in.	418·78	—83·24		—12·51		593·45	4·29	0·17	1·27	
1937-38	6 in.	565·81	—63·65	9·01	—23·81	6·17	566·41	103·04	2·16	0·40	18 July
	9 in.	518·85	—83·42		—22·30		605·27	70·03	1·61	0·57	10 July
	12 in.	465·67	—81·73		—4·74		707·20	—48·32	—5·06	11·21	
1938-39	6 in.	479·26	—40·44	8·51	—17·30	5·83	459·40	80·66	2·33	0·47	21 July
	9 in.	447·04	—51·87		—18·18		459·40	75·07	2·70	1·11	27 July
	12 in.	400·46	—78·33		—10·41		577·54	—5·49	—0·26	2·14	
1939-40	6 in.	443·24	—34·89	7·30	—17·07	4·99	406·10	84·59	2·48	0·37	23 July
	9 in.	416·48	—56·51		—11·66		505·43	25·14	1·08	1·09	2 July
	12 in.	362·83	—74·04		—3·79		598·33	—50·88	—6·72	—12·90	
1940-41	6 in.	430·19	—59·76	8·24	—21·19	5·64	441·56	88·59	2·09	0·42	17 July
	9 in.	391·67	—66·60		—16·27		472·97	47·28	1·45	0·76	8 July
	12 in.	354·07	—82·37		—11·35		536·46	—2·90	—0·13	—1·85	

Summary

The results of a complex cultural experiment with three winter varieties of rice conducted at the Dacca Farm in five successive seasons from 1936-37 to 1940-41 have been studied with respect to the best date of planting and best spacing between plants. It has been found that for yield of grain all the varieties gave similar results consistently over the five years with regard to the other factors namely, dates of planting and spacings. The best date of planting differs for the three spacings. Thus with 6 in. spacing the best date of planting is in the second half of July and with 9 in. spacing it is in the first half. The 12 in. spacing gives poor results and the best date could not be estimated with reasonable accuracy. As regards yield of straw the optimum is reached with the smallest spacing and the earliest date of planting.

Though there was wide variation in mean yields of plots for the five seasons there was no interaction between the experimental factors and seasons which is a clear indication that the results obtained about influence of dates of planting and spacings have a wide inductive basis.

REFERENCES

Fisher, R. A. and Yates, F. (1943). *Statistical Tables* (second edition, 1943)

Sukhatme, P. V. (1938). On Fisher and Behrens' test of significane for the difference in means of two normal samples, *Sankhya* **IV**, 39-48

Yates, F. and Cochran, W. G. (1938). The Analysis of Groups of Experiments. *J. agric. Sci.* **28**, 556-80

APPENDIX

Calculation of standard errors of orthogonal coefficients of the yield-date parabolic curve

If the mean yields per plot in any particular year and for a given spacing are $y_1, y_2, \ldots\ldots y_6$ for the six dates of planting, the linear and quadratic orthogonal coefficients of the yield-date curve for that spacing are given by [Fisher and Yates, 1943]

$$B=\tfrac{1}{35}\ [5\ (y_6-y_1)+3(y_5-y_2)+(y_4-y_3)] \qquad (1)$$

$$C=\tfrac{1}{56}\ [5\ (y_1+y_6)-(y_2+y_5)-4\ (y_3+y_4)] \qquad (2)$$

The variances of B and C in terms of variance of a single difference between two values of y are given by

$$V(B)=(\tfrac{1}{35})^2\ (5^2+3^2+1^2)\ V\ (y_i-y_j) = 1/35\ V\ (y_i-y_j) \qquad (3)$$

$$V\ (C)=(1/56)^2\ (5^2+1^2+4^2)\ V\ (y_i-y_j) = 3/224\ V\ (y_i-y_j) \qquad (4)$$

In terms of symbols of treatment combinations, namely $v_1\ v_2,\ v_3$ for the varieties ; $d_1, d_2, \ldots\ d_6$ for dates ; and s_1, s_2, s_3 for spacing, the value of y_i-y_j for a given spacing, say s_1 is given by

$$y_i-y_j=s_1\ (v_1+v_2+v_3)\ (d_i-d_j)/9 \qquad (5)$$

The right hand side of (5) can be expressed in terms of main effect of dates and the interaction between spacing and date. Thus—

$$27(y_i-y_j)=(s_1+s_2+s_3)\ (v_1+v_2+v_3)\ (d_i-dj) +[(s_1-s_2)+(s_1-s_3)]\ (v_1+v_2+v_3)\ (d_i-d_j) \qquad (6)$$

Therefore

$$(27)^2\ V\ (y_i-y_j)=V\ [(s_1+s_2+s_3)\ (v_1+v_2+v_3)\ (d_i-d_j)] + V\ (2\ \ s_1-s_2-s_3)\ (v_1+v_2+v_3)\ (d_i-dj)] \qquad (7)$$

Since 54 plots are involved in the main effect component with coefficients +1 and —1 for 27 each, the variance of that component is 54 times Error Variance (II).

In the interaction component the 54 plots involved have coefficients +2, —1 in 18 and 36 plots respectively, so that the variance of their component is $[18\ \ (2)^2\times 36\ \ (-1)^2]\times$ Error Variance (IV). Therefore $(27)^2\ V\ (y_i-y_j)$=54 Error (II) + 108 Error (IV)

$$\text{or } V(y_i-y_j)=\tfrac{2}{9}\left(\frac{\text{Error (II)}+2\ \text{Error(IV)}}{3}\right) \qquad (8)$$

Substituting (8) in (3) and (4) we get

$$V\ (B)=\tfrac{2}{315}\left(\frac{\text{Error (II)}\ +\ 2\ \text{Error (IV}}{3}\right) \qquad (9)$$

$$V\ (C)=\tfrac{1}{336}\left(\frac{\text{Error (II)}\ +2\ \text{Error (IV)}}{3}\right) \qquad (10)$$

If B_1, B_2, B_3 stand for the linear coefficients of the yield date curve corresponding to spacings 6 in., 9 in., 12 in., variance of difference between any two B's has to be calculated as follows :—

Symbolically,

$$B_1-B_2=\left(\frac{1}{35\times 9}\right)[5\ (d_6-d_1)+3(d_5-d_2)+(d_4-d_3)]\ (s_1-s_2)\ (v_1+v_2+v_3) \qquad (11)$$

where any combination of the symbols d, s and v stands for the total of 3 replicated plots. The contrast involved in (11) consists of elementary contrasts of the type $(d_i-d_j)\ (s_1-s_2)$, that is, of the interaction between dates and spacings. Therefore,

$$V\ (B_1-B_2)=\left(\frac{1}{35\times 9}\right)^2\ \ [(5^2+3^2+1^2)\ \ 36]\times \textit{Error Variance (IV)}$$

$$\textit{Variance (IV)}=\frac{4}{315}\times \textit{Error Variance (IV)} \qquad (12)$$

Similarly, if C_1, C_2, C_3 are the values of the quadratic coefficients of the yield-date curve corresponding to the spacings 6 in., 9 in., 12 in.

$$C_1-C_2=\frac{1}{56\times 9}[5\ \ (d_1+d_6)-(d_2+d_5)-4\ \ \ (d_3+d_4)]\ \ (s_1-s_2)(v_1+v_2+v_3) \qquad (13)$$

$$V\ \ (C_1-C_2)=\left(\frac{1}{56\times 9}\right)^2\ \ [(5^2+1^2+4^2)\ \ \ 36]\times \text{Error Variance (IV)}$$

$$\textit{Variance (IV)}=\frac{1}{168}\times \textit{Error Variance (IV)} \qquad (14)$$

To test whether B and C are significantly different from 0, the Behrens and Fisher test has to be employed. But the different values of B or of C can be compared by the usual t-test with 72 degrees of freedom.

PLANT QUARANTINE NOTIFICATIONS

Notification No. F. 16-3/43-A., dated the 28th March 1944 of the Government of India in the Department of Education, Health and Lands.

In exercise of the powers conferred by sections 4A and 4D of this Destructive Insects and Pests Act, 1914 (II of 1914) the Central Government is pleased to prohibit, with effect from the 1st May 1944, the transport from the Province of Madras to any other Province of any of the articles specified in the First Schedule hereto annexed (being articles which are likely to carry the destructive insect known as Icerya Purchasi and thereby cause infection to crops) :—

(*a*) by letter or sample post, or by air ; or

(*b*) by road, except by such routes as may be specified by the Government of such other Province ; or

(*c*) by rail or inland steam vessel, unless the consignment is accompanied by a certificate in the form set out in the Second Schedule hereto annexed and signed by the Entomologist to Government, Madras, Coimbatore, or such other officer as the Director of Agriculture, Madras, may authorize in this behalf.

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1. The following plants (but not the fruits thereof) namely *Sophora glauca*, Silver Wattle (*Acacia dealbeta*), Black Wattle (*Acacia decurrens* and *Acacia mollissima*), Australian blackwood (*Acacia melanoxylon*), Broom (*Cytisus scoparius*), *Ulex europaeus*, Potato creeper (*Solanum jasminoides*, *Solanum Seaforthianum* and other climbing *Solanums*), all citrus species including all types of orange, lime, lemon, pomeloe and grape-fruit plant, apples (all *pyrus* species), all Eucalyptus species including (*Eucalyptus spectabilis* and *Eucalyptus glauca*, *Rhodomyrtus tomentosa*, *Hypericum mysorense*, Dodonea/Bandedu (Telugu)/Aliar (*Dodonea viscosa*), *Berberis tinctoria*, Rose (*Rosa species*), *Gaultheria fragrantissima*, Raspberry, country pears, *Bougainvillea*, *Verbena*, Mangolia, Pepper, Tea, Casuarina.

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3. Any articles used in packing or wrapping up any of the plants or plant materials mentioned above.

THE SECOND SCHEDULE

Form of certificate

This is to certify that the living plants/plant materials included in the consignment of which particulars are given below were thoroughly examined on (date) by (name and designation of official), a duly authorized official of the (name of the Department) and that the consignment including the packing covered by this certificate has been adequately treated and fumigated with hydrocyanic acid gas immediately prior to inspection and made free from Living *Icerya Purchasi*.

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Particulars of consignment.....

No. and description of packages.....

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Description of living plants or plant materials
....

Exported by .....

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Designation

The above certificate should be signed by the Entomologist to Government, Madras, Coimbatore, or such other officer as may be authorized by the Director of Agriculture, Madras, in this behalf.

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